Modelling the Effect of UK Energy Policy and Climate Change

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Abstract

The central aim of this thesis is to investigate various UK energy policy documents and identify how they are implanted to the main energy consuming sectors in order to achieve a reduction of 60 percent of carbon emissions by 2050. This has lead to two key questions:

- What are the pros and cons of the various UK energy policy documents?
- What are the impacts of currently proposed environmental policies in UK on economic growth in the 21st century?

To answer these questions, the following four energy policy documents are reviewed.

- UK Energy White Paper
- Energy Efficiency Commitment
- Climate Change Levy and UK Emissions Trading Scheme
- Renewable Obligations

Also, the following macro energy modelling work is also investigated:

- Markal Model
- E3ME

The UK Energy White Paper has shown the government is being very eager to solve the climate change and its associated problems by reducing carbon dioxide emissions by 60 percent by 2050. The four documents have illustrated the UK government main strategies to tackle climate change; they are based on developing new technology, improving energy efficiency and to increase the use of renewables considerably. The analysis of these policies and macro-scale model has forecasted that the UK is going to have a slow down economic growth due to the environmental pressure.

Acknowledgements

I would like to thank you my supervisors, Dr Ben Croxford and Dr Mike Davies, for their constructive advice and support during my time of study in the Bartlett.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Chapter Overview

This chapter provides the motive and content for undertaking this thesis. The aims and objectives are described here. Then, a methodology overview of the thesis is established to explain the approach taken to complete the thesis.

1.2 Climate Change and the World today

The first IPCC[1] Scientific Assessment in 1990 concluded that the global temperature has risen by about 0.6°C (±0.2°C) over land and sea level since the beginning of the 20th century[2] and the magnitude of this warming was broadly consistent with the predictions of climate models forced by increasing concentrations of greenhouse gases. The current warming trend is expected to cause extinctions. Numerous plant and animal species, already weakened by pollution and loss of habitat, are not expected to survive the next 100 years. Human beings, while not threatened in this way, are likely to face mounting difficulties, for example, the recent severe storms, floods, and droughts across Northern Europe. The increased temperatures cause ocean volume to expand, and melting glaciers and ice caps add more water. The average sea level rose by 10 to 20 cm during the 20th century, and an additional increase of 9 to 88 cm is expected by the year 2100. If the higher end of that scale is reached, the sea could overflow the heavily populated coastlines of such countries as Bangladesh.

Climate change is directly link to energy consumption, as this is caused by the burning of fossil fuel which releases carbon dioxide (the main greenhouse gas) to the atmosphere. In a country's economical point of view, reducing carbon dioxide released to the Earth's atmosphere means less fossil fuel is being used. Each year, developed countries are willing to buy and extract as much fossil fuel as they can afford to maintain its strong economic. However, the fuel price has increased considerably (together with the interest rate) and developed country finds this very difficult to cope. Climate change and fuel crisis will change the way developed country operate as a whole in upcoming future. Therefore, this country has to find a way to ease this energy problem. This leads to the concept of regulating the use of energy by some sorts of law and energy policy. This policy is updating frequently to suit and adapt the ever changing environment. The primary goal of this policy is to

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[1] **The Intergovernmental Panel on Climate Change** (IPCC) has been established by WMO and UNEP to assess scientific, technical and socio- economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation.

[2] IPCC **Scientific Assessment** in 1990 (IPCC, 1990)

minimise the effect of climate change but at the same time to encourage a country's economy to grow. Energy policy helps 'WE' to act together to make changes effectively. For example, in UK, climate change levy is applied to encourage companies from different sectors to work together, to reduce energy consumption and CO_2 emission.

On international scale, over a decade ago most countries have recognised the climate change problem and they joined an international treaty, the United Nations Framework Convention on Climate Change (UNFCCC) to begin to consider what can be done to reduce global warming and to cope with whatever temperature increases are inevitable. The IPCC's findings, because they reflect global scientific consensus and are apolitical in character, form a useful counterbalance to the often highly charged political debate over what to do about climate change. IPCC reports are frequently used as the basis for decisions made under the Framework Convention, and they played a major role in the negotiations leading to the **Kyoto Protocol**, which has more powerful measures. Kyoto Protocol is a law, if any of the participating countries exceed their proposed 2012 target, they will then have to make the promised reductions from the 2012 target and an additional 30% more in the next period.

World leaders have taken a step forward to discuss the future of the world changing climate as part of the discussion in the recent G8[3] summit.

The importance of climate change has spread to the field of 'art'. United States artist Wayne Hill had devised the art work, a two-litre clear plastic bottle filled with melted ice from the Antarctic, to highlight the dangers of global warming; entitled 'Weapon of Mass Destruction[4]'. The value of this two-litre of water was worked out from the environmental impact of the entire ice sheet melting and the relative amount of damage from two-litres of water.

[3] G8 stands for Group of Eight. The idea is that the eight most powerful countries get together every year and try to find solutions to world problems, like Aids, poverty, the environment, peace in the Middle East, rebuilding Iraq etcetera.

[4] BBC news, http://news.bbc.co.uk/1/hi/england/devon/4718573.stm

1.3 Content: How does the UK government tackle climate change?

The UK has signed up to the Kyoto Protocol[5]. Individually, each country has developed its own method to meet its targets. The EU has setup a market by which 12,000 factories and power stations are given a carbon dioxide quota. If they exceed this amount they can purchase extra allowances or pay a financial penalty. If they fall below the amount they can sell on the extra quota. What about the UK?

Prime Minister, Tony Blair says the government is firmly committed to tackling climate change. The UK are now committed to reducing emissions of the six greenhouse gases, responsible for heating up our atmosphere, by 12.5% below their 1990 levels over the next ten years, which this is done by introducing UK Energy White Paper, published in March 2003.

1.4 Aims and Objective

The aim of this thesis is examine relationship between climate change and energy consumption in UK, and to explore various UK energy policy documents and how they are implanted to achieve a reduction of 60 percent of carbon emissions by 2050. The future outlook of the UK climate change by looking at macro-scale climate change and energy models are looked at.

The research questions are:

- What are the pros and cons of the various UK energy policy documents?
- What are the impacts of currently proposed environmental policies in UK on economic growth in the 21st century?

In order to achieve these aims and answer these questions, the following objectives have been set out.

- Investigate the UK climate change.
- Present UK climate change data.
- Identify and investigate the main cause of UK climate change.
- Review selective UK energy policy documents
- Investigate and present macro-scale energy model.

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5 After seven years of debate between leaders, politicians and scientists, on 16th February 2005 the 1997 Kyoto Protocol to control climate change finally became international law. The Protocol was drawn up in Kyoto, Japan in 1997 to implement the United Nations Framework Convention for Climate Change

1.5 Methodological Overview

This thesis uses a mixed approach to investigate the central question of this thesis. The key methods are:

- Critical review of existing literature;
- Analyse secondary data sources.

Since the question concerns about the whole UK sector, in many cases the quantitative data are obtained from government statistics. The Department for Environment, Food and Rural Affairs (Defra) has provided useful information related to climate change, climate change levy, energy use and environmental related issues. Whereas the Department of Trade and Industry (Dti) has provided helpful information and statistical data related to UK energy white paper and UK business sector. This thesis concentrates on numerical and policy analysis, with some economic analysis. There are always changes to government policy and new research results being published, therefore the material presented is up to the end of August.

1.6 Thesis Structure

The overview of the thesis structure is show in a flow diagram in Figure 1.1.

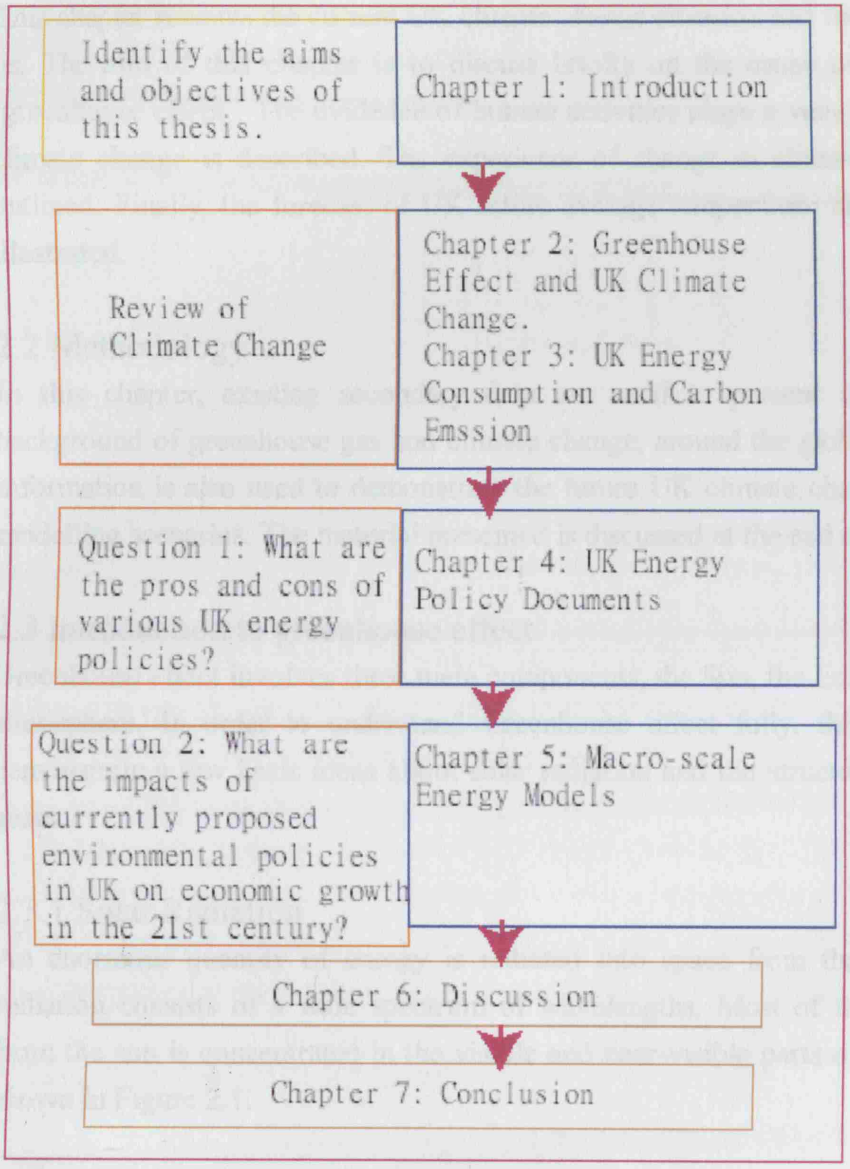

Figure 1.1: Overview of thesis structure

Chapter 2: Greenhouse Effect and UK Climate Change

2.1 Chapter Overview

This chapter reviews the current UK climate change situation and the threat implies to us. The aim of this chapter is to discuss briefly on the cause of climate change, 'greenhouse effect'. The evidence of human activities plays a very important role on climate change is described. The experience of change in climate trend in UK is outlined. Finally, the forecast of UK future average temperature and precipitation is illustrated.

2.2 Methodology

In this chapter, existing secondary data are used to present and introduce the background of greenhouse gas and climate change, around the globe and in UK. The information is also used to demonstrate the future UK climate change under several modelling scenarios. The material presented is discussed at the end of the chapter.

2.3 Introduction to greenhouse effect

Greenhouse effect involves three main components, the Sun, the Earth and the Earth's atmosphere. In order to understand Greenhouse effect fully, this is important to demonstrate a few basic ideas about solar radiation and the structure of atmospheric gases.

2.3.1 Solar Radiation

An enormous quantity of energy is radiated into space from the sun, which this radiation consists of a wide spectrum of wavelengths. Most of this radiant energy from the sun is concentrated in the visible and near-visible parts of the spectrum, as shown in Figure 2.1.

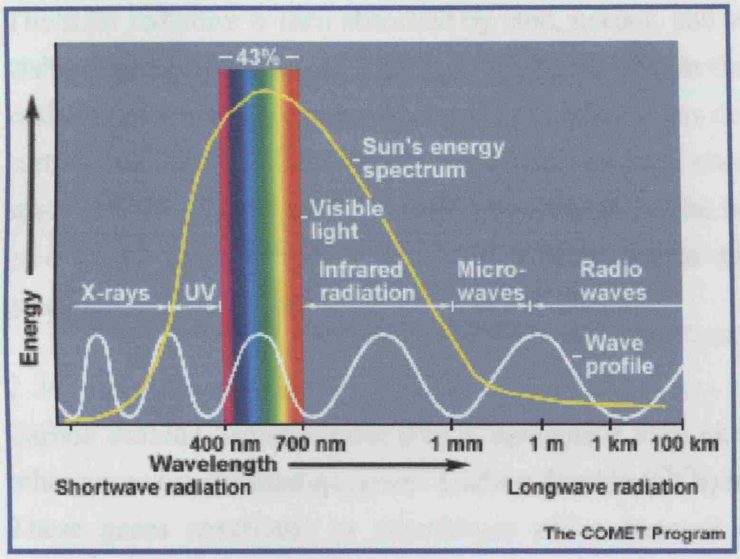

Figure 2.1: Light Spectrum[6]

The narrow band of visible light, between 400 and 700 nm, represents 43% of the total radiant energy emitted. Wavelengths shorter than the visible account for 7 to 8% of the total, but are extremely important because of their high energy per photon. The shorter the wavelength of light, the more energy it contains i.e. ultraviolet light (UV) is very energetic and it is capable of breaking apart stable biological molecules and causing sunburn and skin cancers. The remaining of the radiant energy is spread over the wavelengths longer than those of visible light, this is the Infrared radiation (near infrared, thermal infrared and far infrared). Various components of earth's atmosphere absorb ultraviolet and infrared solar radiation before it penetrates to the surface, but the atmosphere is quite transparent to visible light. This is shown in Figure 2.2.

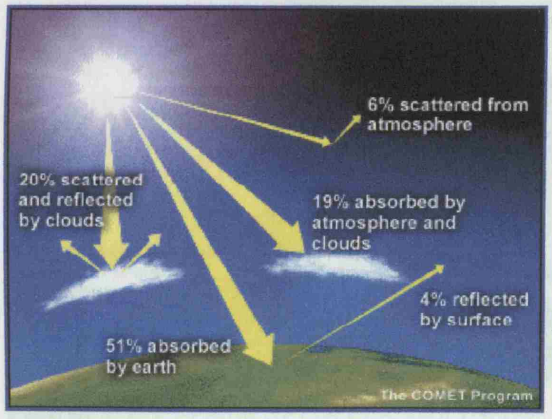

Figure 2.2: The Mechanism of the Earth's Atmosphere[7]

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[6] University Corporation for Atmospheric Research http://www.ucar.edu/learn/1_3_1.htm

The solar radiation is then absorbed by land, oceans, and vegetation at the surface, the visible light is transformed into heat and re-radiates in the form of invisible infrared radiation. If the Earth's atmosphere and greenhouse gas do not present, during the day earth would heat up, but at night, all the accumulated energy would radiate back into space and the planet's surface temperature would fall far below zero very rapidly. The greenhouse gas can reduce the heat radiated out to space. More information on greenhouse gas is discussed in the next sub-chapter.

2.3.2 Greenhouse Gases (GHG)

Carbon dioxide, water vapour (H_2O), methane (CH_4), nitrous oxide (N_2O), and a few other gases are greenhouse gases. Carbon dioxide (CO_2) is the main greenhouse gases. These gases contribute to greenhouse effect because of their chemical bonding properties as they are molecules composed of more than two component atoms, bound loosely enough together to be able to vibrate with the absorption of heat. The origin of vast qualities of CO2 released to the atmosphere is discussed in Chapter 3. The carbon dioxide molecule can absorb infrared radiation causing the molecule to vibrate; the vibrating molecule will then emit the radiation again. This emitted radiation is very likely to be absorbed by another greenhouse gas molecule. This absorption-emission-absorption cycle serves to keep the heat near the surface, hence insulating the surface from the cold of space.

2.3.3 Greenhouse Effect

The science behind Greenhouse Effect is very simple; Figure 2.3 shows a simple schematic diagram helps to explain this effect.

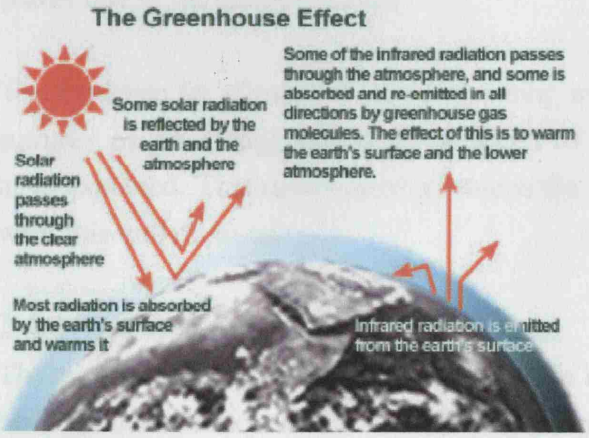

Figure 2.3: Concept of Greenhouse Effect[8]

[7] University Corporation for Atmospheric Research http://www.ucar.edu/learn/1_3_1.htm
[8] Environmental Protection Agency of USA, http://www.epa.gov/globalwarming/kids/greenhouse.html

Earth's atmosphere act as an insulating blanket of just the right thickness, trapping sufficient solar energy to keep the global average temperature in a pleasant range. Earth's atmosphere is a collection of atmospheric gases or greenhouse gases.

Earth receives most of its energy from the Sun, in a form of electromagnetic radiation in the visible spectrum with small amount of Infrared and Ultraviolet radiation. The incoming short wavelength radiation from the Sun can pass through the Earth's atmosphere and reach the Earth's surface. The energy coming in from the sun can pass through the atmosphere almost unchanged and warm the earth, but the infrared radiation emanating from the earth's surface is partly absorbed and re-emitted by greenhouse gas molecules. This further warms the surface of the earth and the lower atmosphere. The gases that do this naturally are mainly water vapour and carbon dioxide. This principle works exactly in a greenhouse and an analogy can be made as follow, *"The sunshine can penetrate the greenhouse glass and the glass keeps the heat in, i.e. greenhouse effect."*

2.4 Introduction to Climate Change

Scientists first used the term 'greenhouse effect' in the early 1800s to describe the naturally occurring functions of trace gases in the atmosphere and did not have any negative connotations. Without this natural greenhouse effect, the earth would be over 30°C cooler and would be too cold to be habitable. But in the mid-1950s the term greenhouse effect was linked with climate change. The negative concerns are related to the rise of greenhouse gas concentrations rise well above their natural levels, the additional warming that will take place could threaten the future sustainability of the planet due to the climate change

The evidence for climate change is growing more alarming each year. The recent hot summer of 2003 suggested that the speed of the warming is faster than one would have expected. This sub-chapter discusses the present and future climate change, and what this will do to us.

2.4.1 The Evidence of Climate Change

The climate is changing was first identified in 1960s[9]. By looking at the concentration of CO_2 concentration in the atmosphere, the potential risk of climate change can be identified. Since 1950s, the Mauna Loa atmospheric CO2 measurements constitute the

[9] Sue Roaf, David Crichton, Fergus Nicol (2005) **Adapting Buildings and Cities for Climate Change. Architectural Press.** pp.6 ISBN 0 7506 5911 4

longest continuous record of atmospheric CO_2 concentration in the world. This site, on the island of Hawaii is the one of the most favourable for measuring undisturbed air. The Mauna Loa record is considered to be precise and reliable indicator of the concentrations of atmospheric CO_2 in the middle layers of the troposphere. Figure 2.4 shows that the Mauna Loa record indicates a 19.4% increase in the mean annual concentration, from 315.98 parts per million by volume (ppmv) of dry air in 1959 to 377.38 ppmv in 2004. The 1997-1998 increase in the annual growth rate of 2.87 ppmv represents the largest single yearly jump since the Mauna Loa record began in 1958. This represents an average annual increase of 1.4 ppmv per year. This is smaller than the average annual increase at the other stations because of the longer record and inclusion of earlier (smaller) annual increases. The levels of CO_2 concentration exceeding about 300 ppm are not seen in the last half million years. This means that CO_2 is now at a level that is higher than in the warmest interglacial periods for the last 4 ice age cycles. Thus, even this long record cannot indicate to us how global temperature might respond to these high levels, which are predicted to continue to increase. Base on this Mauna Loa record, there is an 18% increase of CO_2 content by the year 2000. The Study of Critical Environment Problems (SCEP) suggested that earth temperature can increase by 0.5°C due to the increase of this CO_2 content. This prediction proved to be very close to the recorded warming between 1947 and 1997 of between 0.25 and 0.5°C. This is shown in Figure 2.5.

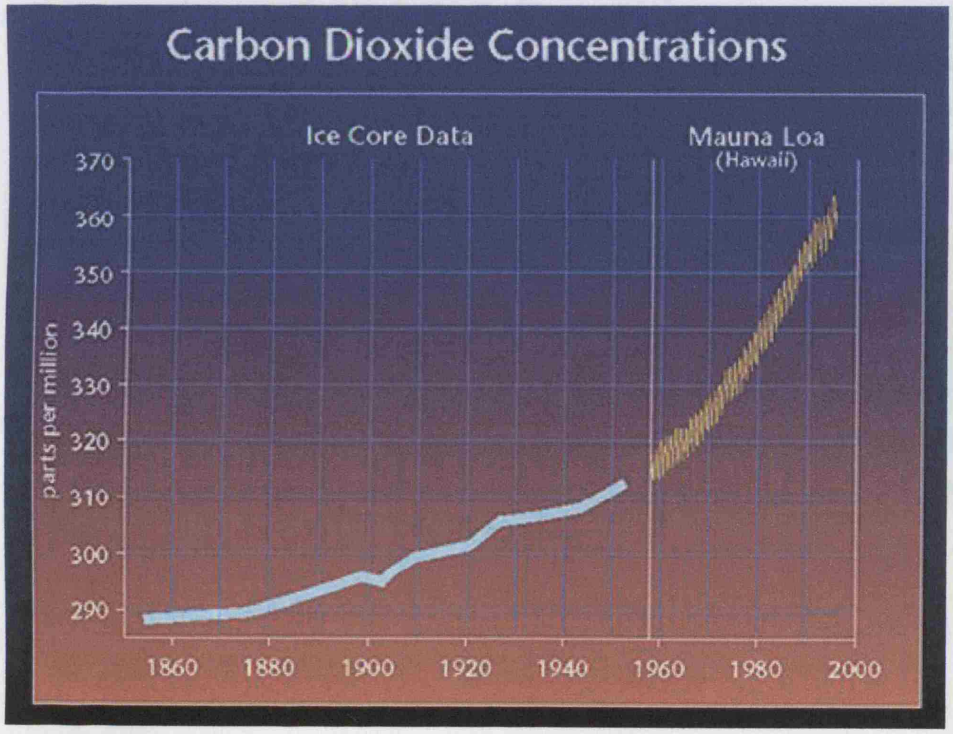

Figure 2.4: Carbon Concentration in the past and present[10]

[10] Earth and Space Research. http://www.esr.org/outreach/climate_change/mans_impact/large/co21.jpg

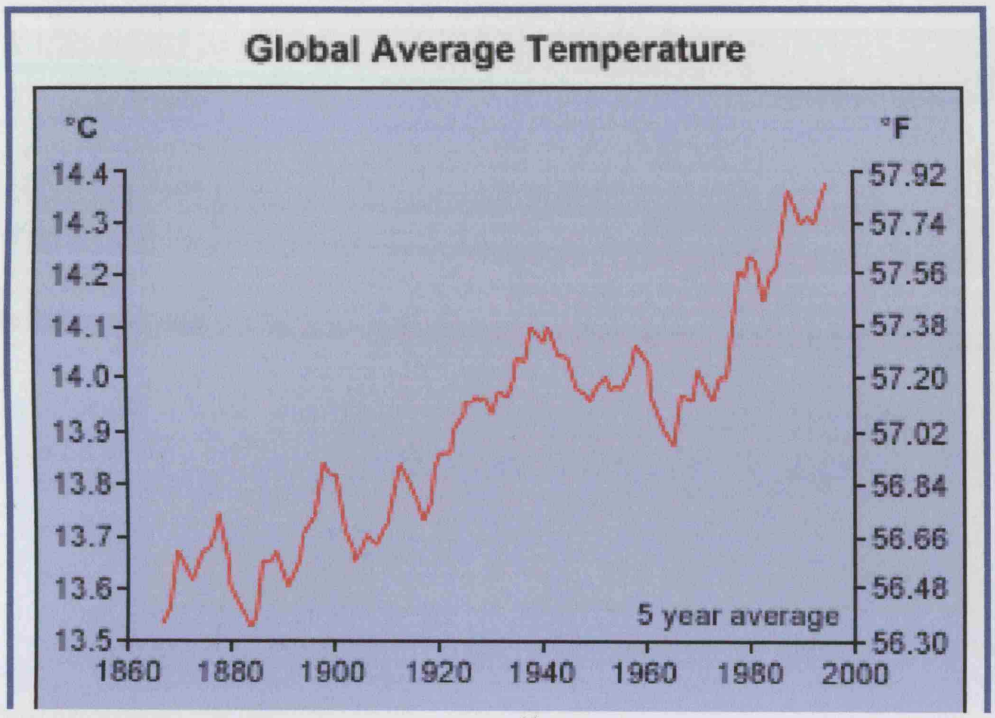

Figure 2.5: Global Average Temperature[11]

2.4.2 The main course of Climate Change – Human Activities and Human-made Greenhouse Gas

The extent to which changes in temperature over the last 100 years are due to human activities has been studied by looking at patterns of change across the surface of the earth, and vertically through the depth of the atmosphere and the ocean. Climate models predict a characteristic 'fingerprint' pattern of change in response to increasing greenhouse gas concentrations. Statistical analysis shows that this fingerprint can be detected in observed temperature changes, indicating that most of the change which has occurred can be attributed to human activities. The individual contributions of natural effects, for example, variations in the sun's output and volcanoes, have also been studied. They were found to be unable to account for all of the observed warming. Only when greenhouse gases emitted by human activities are invoked can the observed warming be explained. Borehole measurements worldwide imply a global surface warming of around 1°C during the last 500 years, with about half of this warming occurring in the 20th Century.

[11] University Corporation for Atmospheric Research http://www.ucar.edu/learn/1_4_1.htm

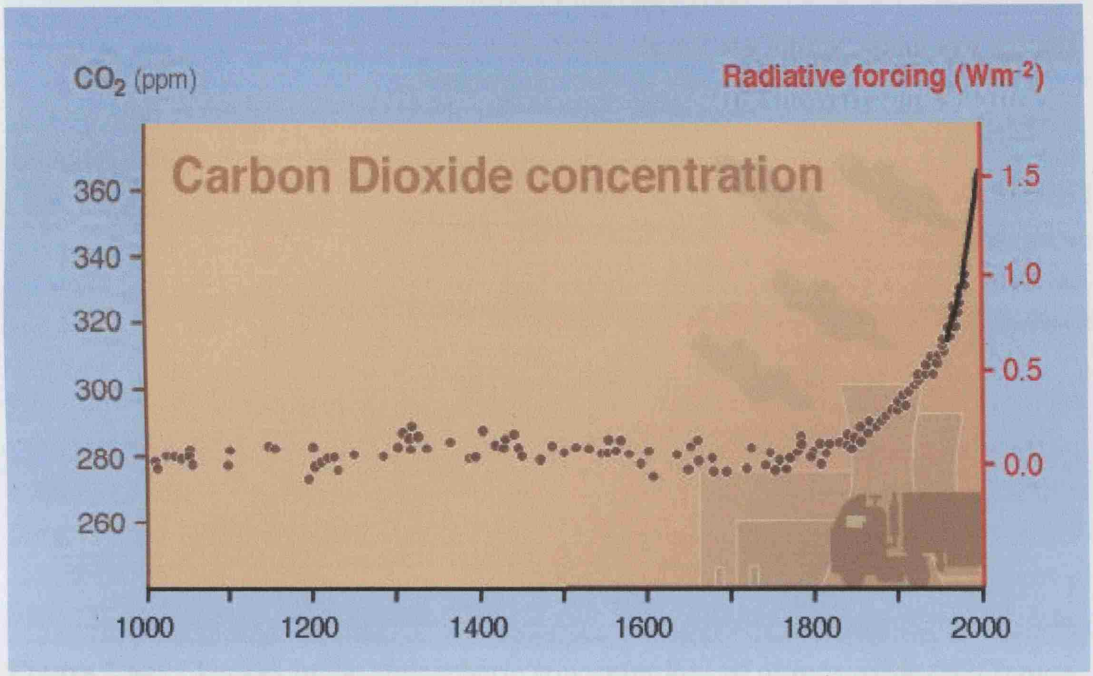

Figure 2.6a: Changes in the atmospheric concentrations of carbon dioxide (CO2) over the past 1000 years

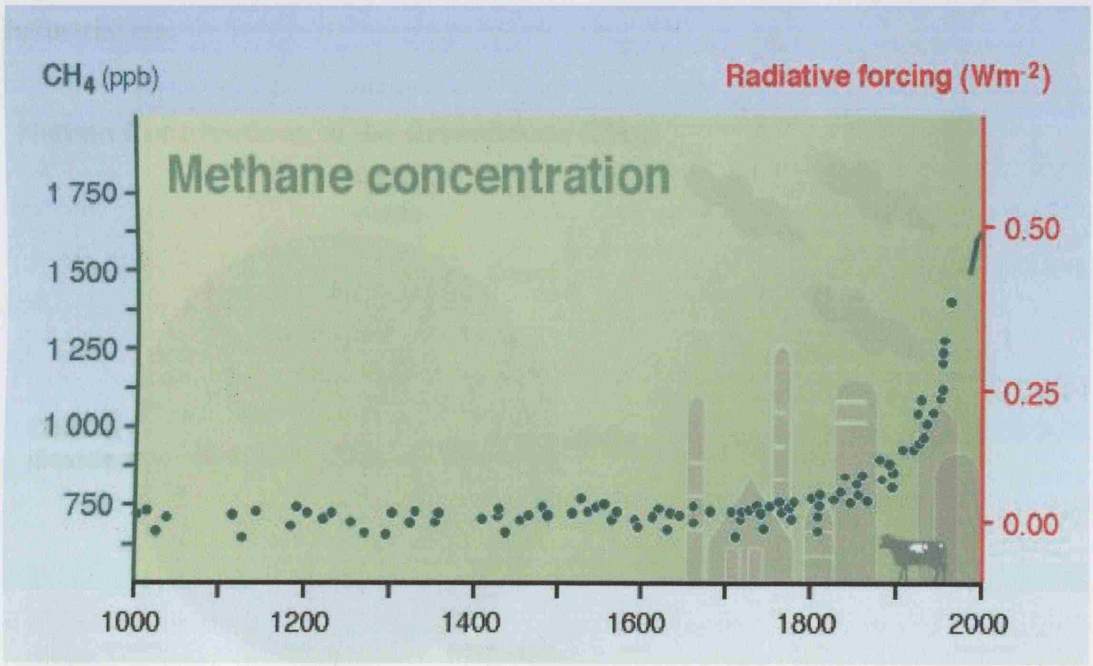

Figure 2.6b: Changes in the atmospheric concentrations of methane (CH4) over the past 1000 years

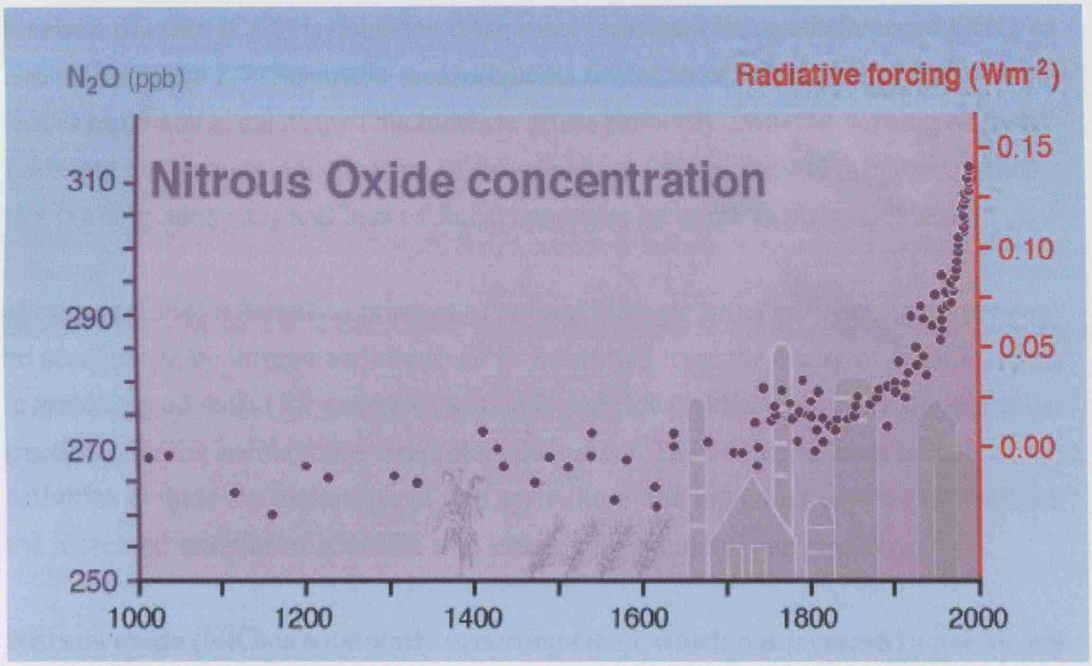

Figure 2.6c: Changes in the atmospheric concentrations of nitrous oxide (N2O) over the past 1000 years

Figure 2.6a, b and c[12] show the human influence on the atmosphere during the Industrial era.

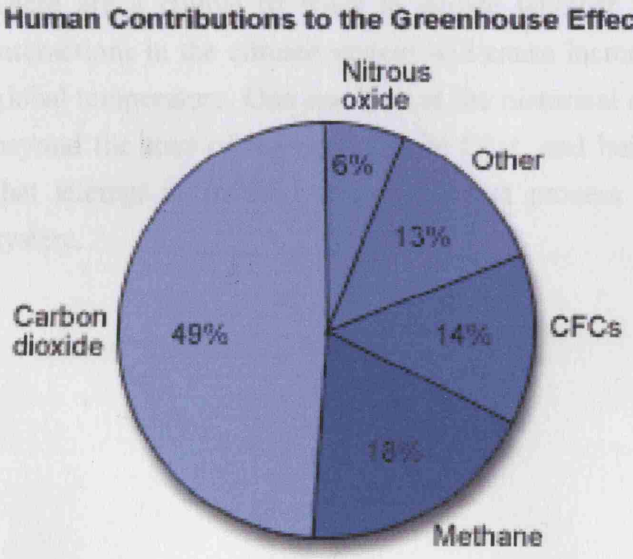

Figure.2.7: Pie Chart Showing Human Contributions to the Greenhouse Effect[13]

[12] The Intergovernmental Panel on Climate Change
http://www.ipcc.ch/present/graphics/2001syr/small/02.01.jpg

[13] University Corporation for Atmospheric Research http://www.ucar.edu/learn/1_4_2_20t.htm

Carbon dioxide (CO_2) is considered the most important human-influenced GHG, as shown in Figure 2.7. Scientific measurements reveal an unmistakable global increase that is rapid and escalating. This increase arises primarily from the burning of fossil fuels and the burning and clearing of forested land for agricultural purposes, which this burning adds CO_2 and loss of forests prevents its usage in photosynthesis.

Methane (CH_4) is largely a product of natural biologic processes, but its output can be accelerated by human activities. CH_4 is emitted from the decay of organic matter in waterlogged soils (for example, wetlands and rice paddies) and from the digestive tracts of grazing animals (for example, ruminants). The additions from human activities include the expansion of rice agriculture, the increased number of livestock, the increased number of landfills, and leakage from natural gas pipelines.

Nitrous oxide (N_2O) is a naturally occurring GHG, which has increased significantly in recent years due to human activity. N_2O is emitted from coal-burning power plants and can be released from the breakdown of chemical fertilizers in the soil.
From these results it is clear that human activities are changing the composition of the atmosphere, increasing the concentration and changing the mix of greenhouse gases. As mentioned earlier, these gases can lead to a rise in the earth's temperature.

There are a couple of ways to decide whether the net effect of all the complex interactions in the climate system will cause increased CO_2 concentration to increase global temperature. One can look at the historical record over a period that goes back beyond the start of the rapid rise in CO2, and build sophisticated numerical models that attempt to model every significant process that occurs in the global climate system.

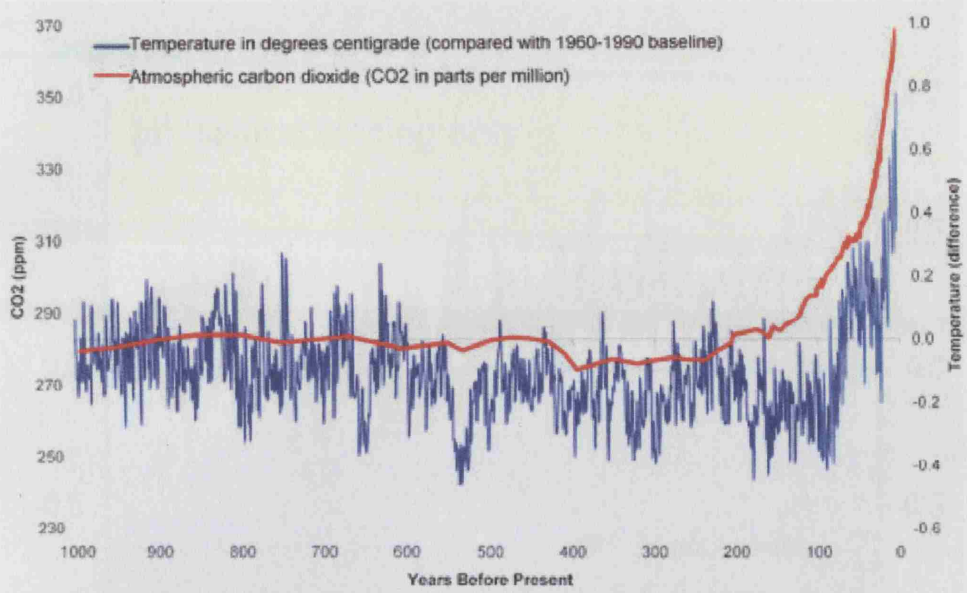

Figure 2.8: Global Temperature Change[14]

Figure 2.8 shows the northern hemisphere temperatures over the past 1000 years as based on climate proxies (dark blue) and thermometer based recording (light blue). CO2 concentrations (red) are those recorded in the Law Dome (Antarctic) ice core and at the Mauna Loa monitoring station in Hawaii.

The figure shows the temperature rises with the rise of CO_2 levels. The actual climate system is a lot more complicated than this. However, this simple study has proven that man is influencing the climate.

Another model has been used to assess man's impact on global surface temperatures. Figure 2.9a compares observed temperatures over the past century with the output from a climate model that has been run without including the anthropogenic greenhouse effect. Figure 2.10b compares observed temperatures with output from a model that incorporates only the greenhouse effect. Figure 2.10c makes the same comparison only with model results that incorporate both greenhouse and natural forcing.

These figures suggest that apart from natural forces, mankind is also having an impact on the temperature change. This leads back to the question posed in the introduction chapters, what 'WE' have to do to tackle climate change.

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[14] United Nation Environmental Program
http://www.unep.ch/ipcc/present/graphics/2001syr/large/05.16.jpg

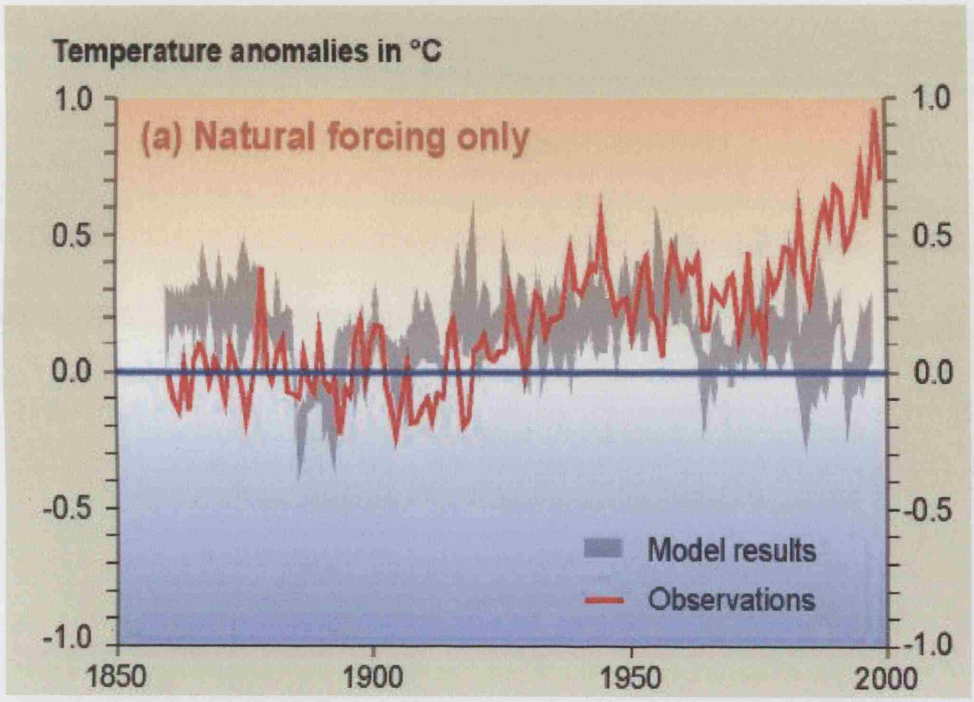

Figure 2.9a: Natural Forcing

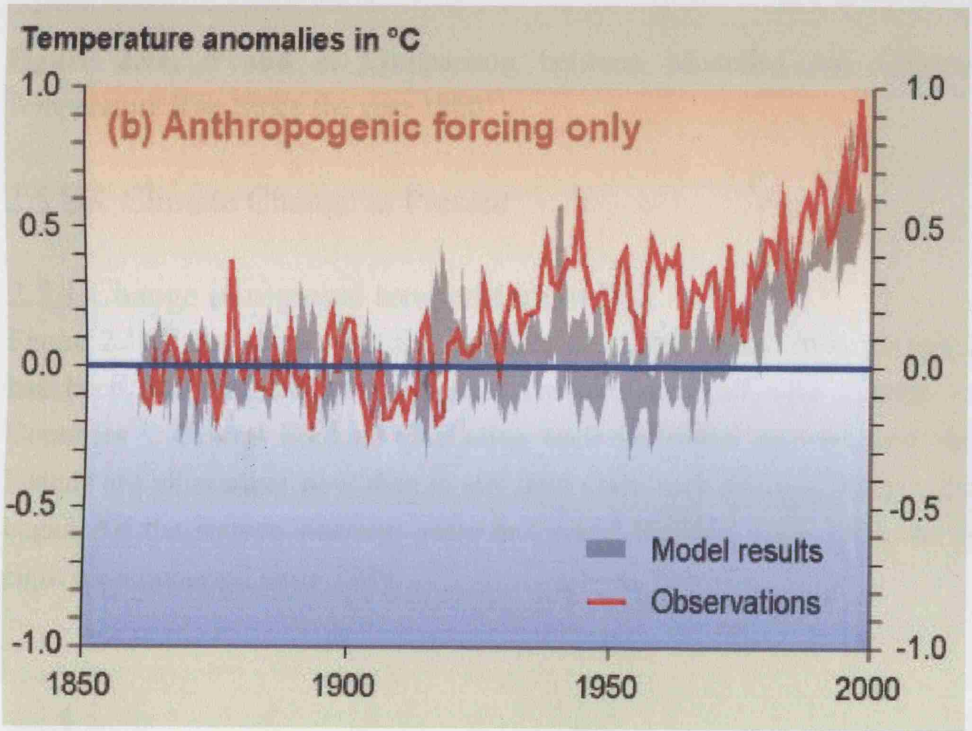

Figure 2.9b: Anthropogenic Forcing

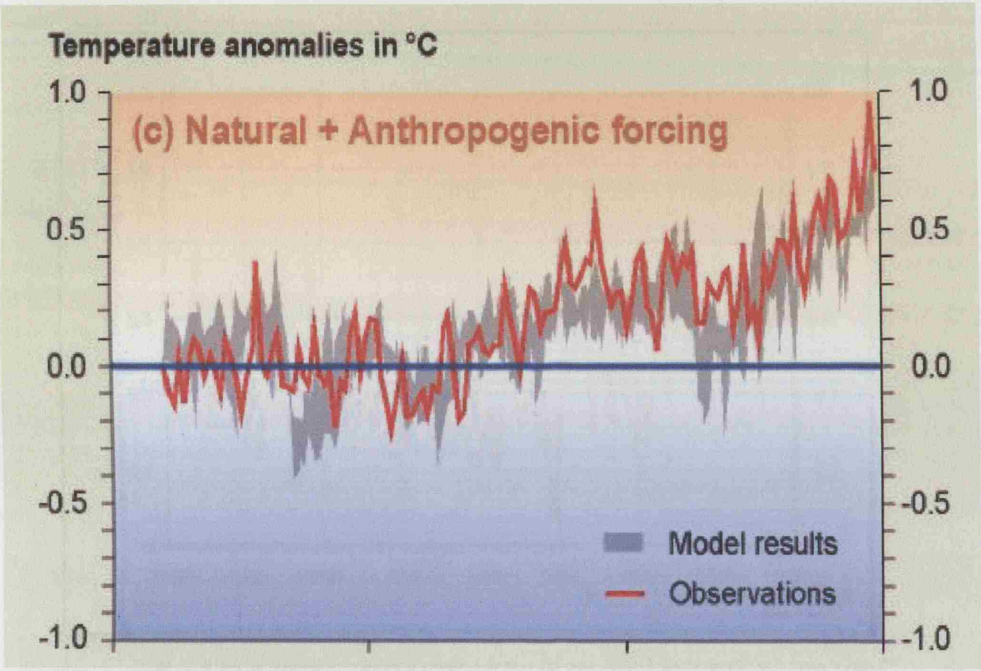

Figure 2.9c: Natural and Anthropogenic Forcing

Figure 2.9a, b and c: Comparison between Modelled and Observations of Temperature Rise Since the year 1860[15].

2.5 UK Climate Change at Present

2.5.1 Change in regional temperature in UK

Figure 2.10[16] has shown that the warming of global climate over the last 140 years has been accompanied by a regional warming in north-west Europe - the Low Countries[17], Central England (including each individual season), and the Scottish Islands are all warmer now than at any time since each of these independent records began. Of the sixteen warmest years in Central England since 1659, no fewer than eight have occurred since 1989.

[15] Intergovernmental Panel on Climate Change (IPCC), 2001: Climate Change 2001: Synthesis Report
[16] UKCIP, **Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report.** Page10.
[17] Region of Europe that consists of Belgium, the Netherlands, and the duchy of Luxembourg.

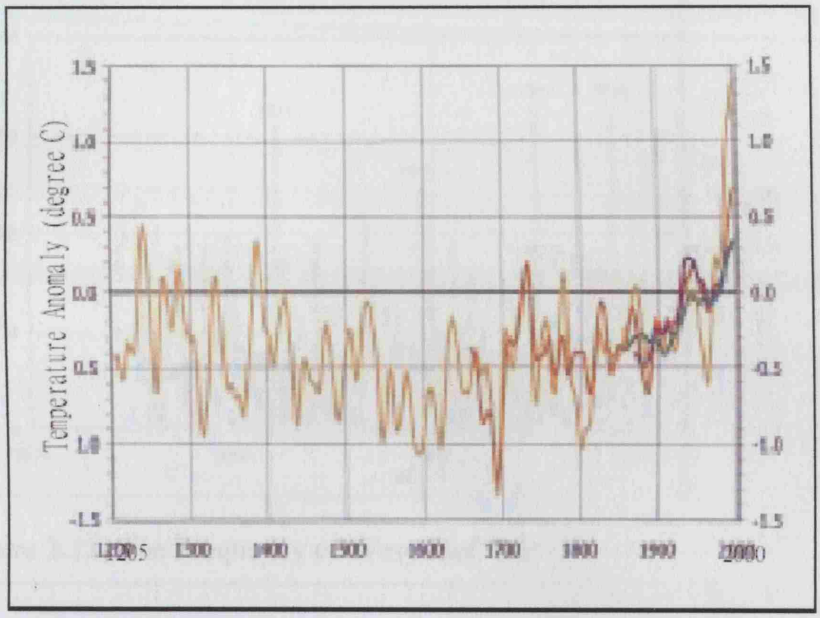

Figure 2.10: ■ = Annual surface temperature for the world (1861 to 2001), ■ = the Low Countries (1205 to 2000, source: Aryan van Engelen), ■ = Central England (1659 to 2001), ■ = Scottish Islands (1881 to 1999, source: SNIFFER report), all expressed as deviations relative to the 1961-1990 average. All curves are smoothed to emphasise variations over time-scales of at least 30 years. Note: the Low Countries temperature is an average of summer and winter temperature.

Figure 2.11 has indicated the warming of UK climate has had consequences for daily temperature extremes. An increase in the frequency of "very hot" days in Central England has occurred since the 1960s, with a number of particularly extreme summers being experienced – 1976, 1983, 1990 and 1995. Extremes of temperature – whether intense cold in winter or intense heat in summer - often have their greatest impact, however, when they are sustained over a number of days. Figure 2.12 has shown "Coldwaves" became less frequent during the twentieth century, particularly during March and November, whereas "heatwaves" became more frequent, particularly during May and July.

In Central England, the 1990s decade (1991 to 2000) was exceptionally warm by historical standards and about 0.5°C warmer than the 1961-1990 average. Since 1990, new records have been set in the 343-year Central England temperature series for – the two warmest years (1990 and 1999), warmest summer half-year (1995), warmest winter half year (1994-95), warmest August (1995), warmest October (2001) warmest November (1994), and the warmest 12-month period (November 1994 to October 1995).

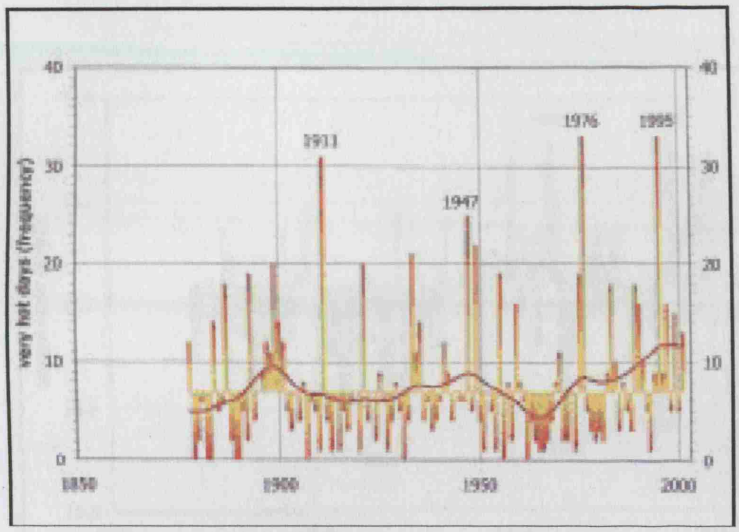

Figure 2.11: The Frequency of 'Very Hot' Day[18]

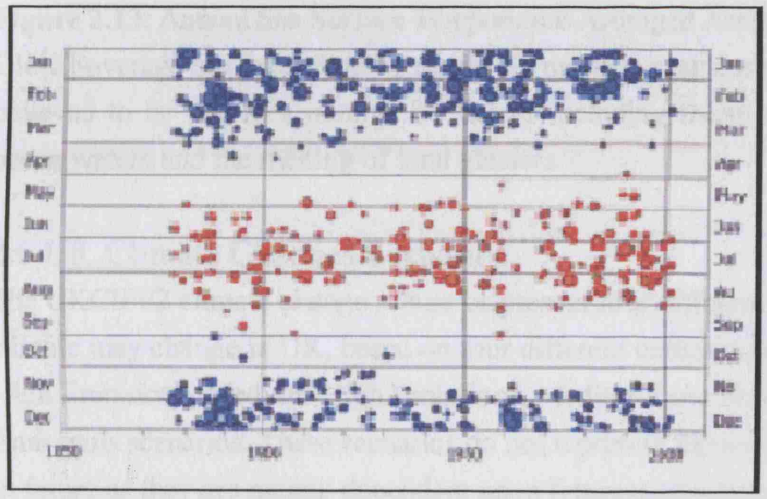

Figure 2.12: The Occurrence of 'heatwaves' (red) and 'coldwaves' (blue), 1878 to 2001[19].

2.5.2 Change in marine climate and sea level

The longest continuing records of sea-surface temperature in UK waters for specific locations (Dover, Eastbourne and Port Erin) show an increase in annually-averaged temperature of about 0.6°C over the last 70 to 100 years, consistent with the warming observed over land. A broader picture of changes in sea-surface temperature in UK coastal waters can be obtained by extracting information from a global marine temperature database. This is shown in Figure 2.13 and also reveals that sea-surface temperature has increased by about 0.5°C during this period, with a substantial increase over the last 20 years.

[18] UKCIP, **Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report.** Page11.
[19] UKCIP, **Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report.** Page11

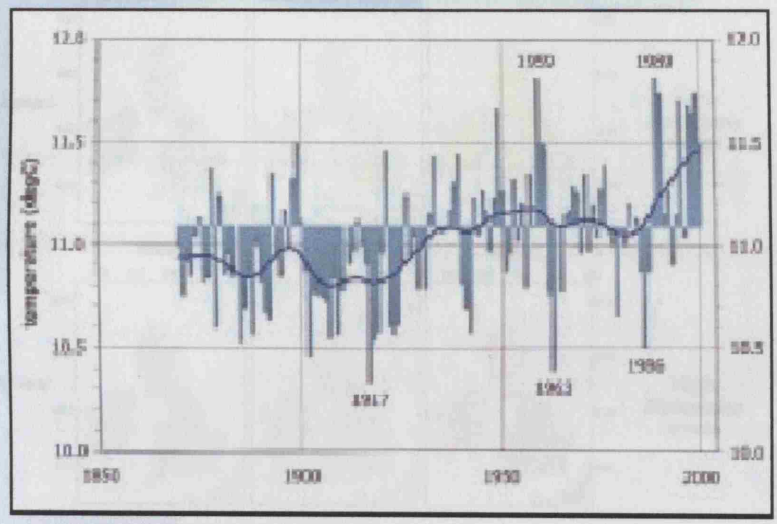

Figure 2.13: Annual Sea Surface Temperature Averaged Around the UK Coastline Global-average sea level rose by about 1.5 mm per year during the twentieth century, believed to be due to a number of factors including thermal expansion of warming ocean waters and the melting of land glaciers.

2.6 UK Climate Changes Scenarios

The UKCIP02 climate change scenarios present four different descriptions of how climate may change in UK, based on four different emission scenarios; they are the High Emissions, Medium-High Emissions, Medium-Low Emissions and Low Emissions scenarios. These scenarios do not represent the actual UK climate change in future as they are mainly dependent upon future greenhouse gas emissions. The scenarios provide alternative views of the future, and together show a broad range of changes that we may face.

2.6.1 Average UK Temperature in Future

Annual warming rates vary from about 0.1° to 0.3°C per decade for the Low Emissions scenario, to about 0.3° to 0.5°C per decade for the High Emissions scenario. The Southeast of England will get very hot indeed by 2080, as shown in Figure 2.14. By contrast, winter warming by the 2080s in northwest Scotland ranges from just 1°C (Low Emissions) to 2°C (High Emissions). The more rapid warming rates in the southeast in summer are likely to be a result of the increased continentality of climate here i.e. drier summers and drying soils leading to larger increases in the sensible and latent heat ratio than in the northwest.

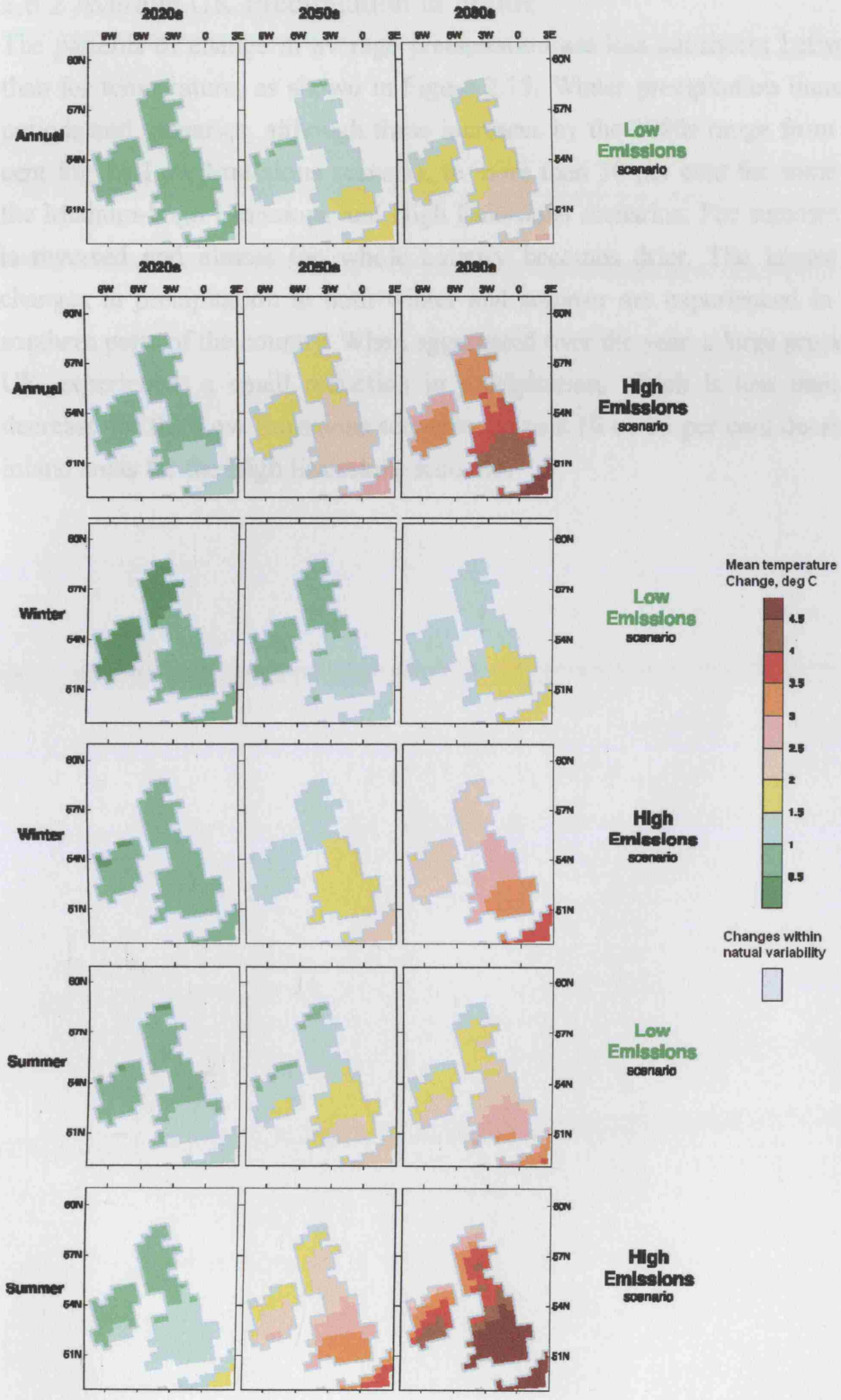

Figure 2.14: Changes in Average Annual, Winter and Summer Temperature for the *Low* and *High Emissions Scenarios*[20].

[20] UKCIP, **Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report.** p.26-32

2.6.2 Average UK Precipitation in Future

The patterns of change in average precipitation are less consistent between seasons than for temperature, as shown in Figure 2.15. Winter precipitation increases for all periods and scenarios, although these increases by the 2080s range from 5 to 15 per cent for the Low Emissions scenario, to more than 30 per cent for some regions for the Medium-High Emissions and High Emissions scenarios. For summer, the pattern is reversed and almost the whole country becomes drier. The largest percentage changes in precipitation in both winter and summer are experienced in eastern and southern parts of the country. When aggregated over the year, a large proportion of the UK experiences a small reduction in precipitation, which is less than 5 per cent decrease for the Low Emissions scenario, up to a 10 or 15 per cent decrease in some inland areas for the High Emissions scenario.

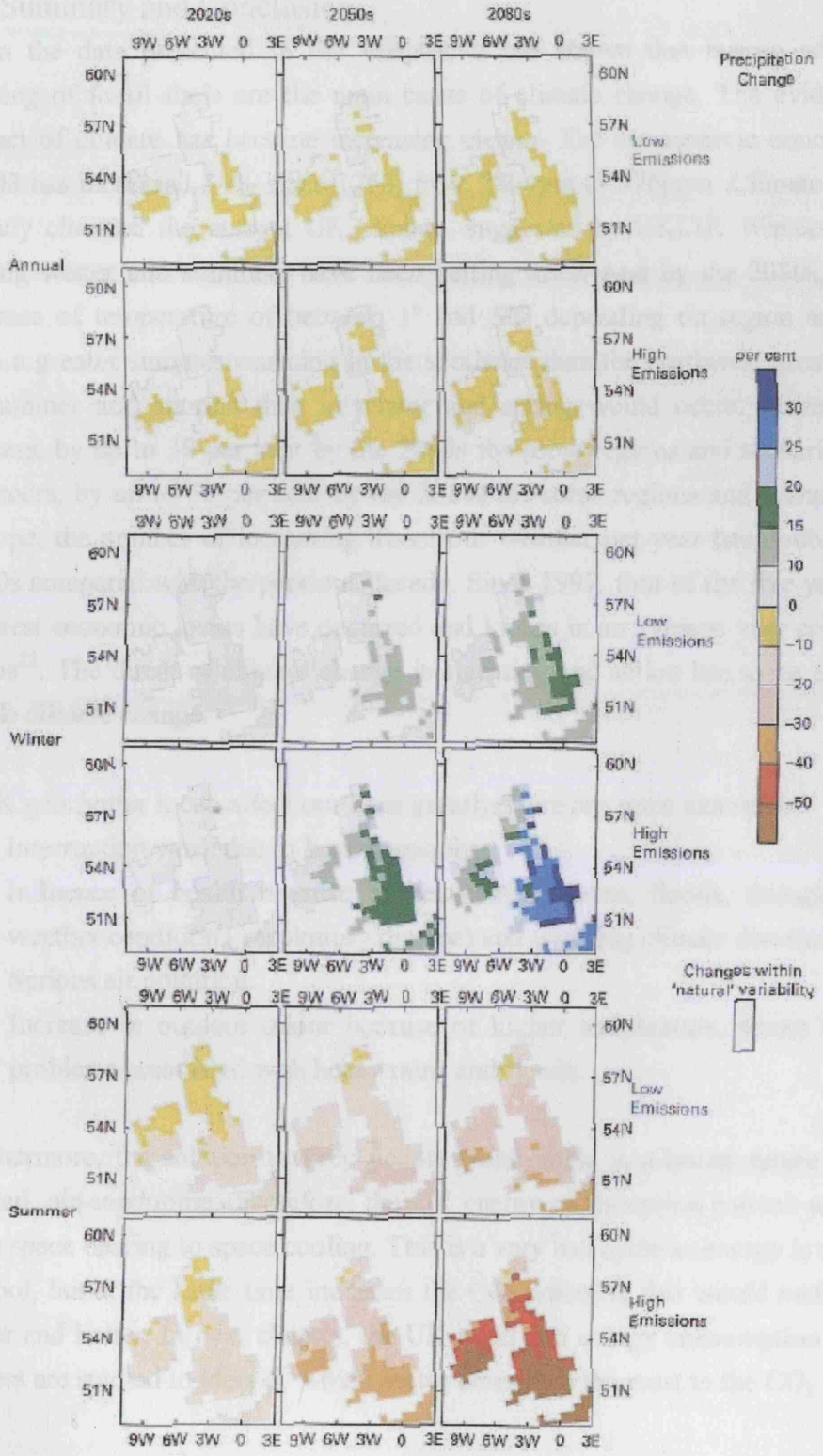

Figure 2.15: Percent Change in Average Annual Winter and Summer Precipitation for the *Low* and *High Emissions Scenarios*[21].

[21] UKCIP, **Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report.** p.33-39

2.7 Summary and Conclusion

From the data presented in this chapter, it has shown that human activities and burning of fossil fuels are the main cause of climate change. The evidence of the impact of climate has become increasing clearer. The atmospheric concentration in 20003 has increased 34% since 1750, from 280ppm to 376ppm. Climate change has already changed the current UK climate, suggested by UKCIP. Winters have been getting wetter and summers have been getting drier. And by the 2080s, there is an increase of temperature of between 1° and 5°C depending on region and scenario. Also a greater summer warming in the southeast than the northwest greater warming in summer and autumn than in winter and spring would occur. Moreover, wetter winters, by up to 30 per cent by the 2080s for some regions and scenarios and drier summers, by up to 50 per cent by the 2080s for some regions and scenarios. Within Europe, the number of increasing disastrous weather per year has doubled over the 1990s compared with the previous decade. Since 1997, four of the five years with the greatest economic losses have occurred and looses in an average year cost 10 billion Euros[22]. The threat of climate change is alarming and action has to be taken now to tackle climate change.

If UK gets hotter it can affect our lives greatly. Here are some examples:

- Interruption work due to heat discomfort.
- Influence of health because of heat-wave, storms, floods, drought, changing weather condition (respiratory disease) and warming climate disease(malaria)
- Serious air pollution.
- Increase in outdoor odour because of higher temperature, waste containment problems associated with heavy rains and floods.

Furthermore, the solution to keep people comfortable in a hotter future has already existed, air-condoning. Therefore, the UK energy consumption pattern would switch from space heating to space cooling. This is a very bad cycle as energy is used to keep us cool, but at the same time increases the CO_2 emission that would make the world hotter and hotter. In next chapter, the UK trend and energy consumption of different sectors are studied to identify which sector contribute the most to the CO_2 emission.

[22] **EEA 2004 environmental signal 2004**, European Environmental agency, Copenhagen

Chapter 3: UK Energy Consumption and CO2 Emission

3.1 Chapter Overview

In the last one hundred years, industrialisation has increased the energy consumption dramatically. Smil[23] has suggested that in the year 2000, the world has consumed about 25 times more useful energy in the commercial sector than it did in 1900. Most importantly, this energy has come from burning fossil fuel. Developed countries in particular put their lives upon fossil fuel; UK derives 90% of its total energy requirement from burning fossil fuels. From Chapter 2, it has shown that climate change is caused by human activities such as burning fossil fuel and deforestation, which these release vast amount of carbon dioxide to the atmosphere. This chapter looks at the energy consumption in UK at present and forecast the trend of energy consumption. The trend of UK energy consumption is very important since this can affect the rate of climate change.

3.2 Methodology

By reviewing Dti document to show and discuss the energy consumption in United Kingdom. This chapter looks at the overall energy consumption in UK as a whole and then the energy consumption by fuel types. Followed by showing the energy consumption in different sectors, to identify which sector uses the most energy. Similar approach is carried on the CO2 emission. Finally, the changing trend of energy consumption and CO2 emission is also explored.

3.3 Conventions of Energy Unit

Energy can be described and measured in the following three ways:

Primary Energy: This is the energy embodied in natural resources e.g. coal, crude oil that has not undergone any anthropogenic[24] conversion or transformation.

Final Energy: This is the energy consumed by final users i.e. energy measured in the meter. This term is used mainly in this thesis.

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23 Smil, V. 2000. **Energy in the 20th century: resources, conversions, costs, uses, and consequences. Annual Review of Energy and the Environment** 25:p.21-51. http://home.cc.umanitoba.ca/~vsmil/pdf_pubs/aree2000-1.pdf

24 Anthropogenic effects or processes are derived from human activities, as opposed to natural effects or processes that occur in the environment without human influences.

Useful Energy: This is the energy available after deduction of losses from final energy. Dti document[25] states that there is lack of data on utilizing efficiencies and on the purposes for which fuels are used.

3.4 UK Energy Consumption and the trend

Million tonnes of oil equivalent Energy consumption in 2001 was higher than in any other year over the last thirty years. Overall energy consumption for energy use in the UK has increased by 13 per cent since 1970 and by 11 percent since 1990.

Final energy consumption in the UK in 2001, as shown in Figure 3.1, was at a higher level than any in other year over the last thirty years. Overall energy consumption has increased by 10 percent since 1970 and by 9 percent since 1990. The fuel mix has changed significantly since 1970 as natural gas consumption has replaced coal. In 1970 natural gas accounted for 3 percent of total overall final energy consumption and in 2001 increased by 36 percent. Electricity consumption has also increased by 74 percent over the period. Over the last 20 years it has grown steadily at 2 per cent a year. Consumption of solid fuels has fallen by 90 per cent between 1970 and 2001.

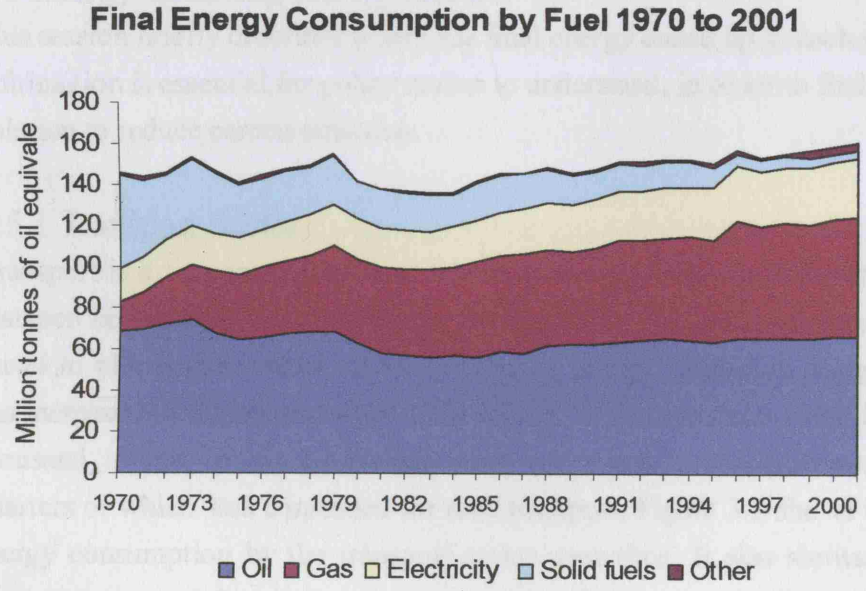

Figure 3.1: Final Energy Consumption by fuel 1970 to 2001[26].

In final energy terms by sector, as shown in Figure 3.2, the transport sector was the largest single consumer of energy in 2001, accounting for 34 per cent of the total. The domestic sector was responsible for a further 30 per cent and industry for another 22

[25] Dti, **Digest of United Kingdom Energy Statistics 2005.** p.21
[26] Dti, **Energy Consumption in United Kingdom**. P.10

per cent. The remaining 14 per cent was consumed by the service sector (13 per cent) and the agriculture sector (1 per cent). Figure 3.2 also shows that since 1990, the contribution that each of these sectors has made to overall energy consumption has not changed greatly, although there have been more major changes since 1970, reflecting the shift from energy-intensive industry to the service sector and growth in the transport sector.

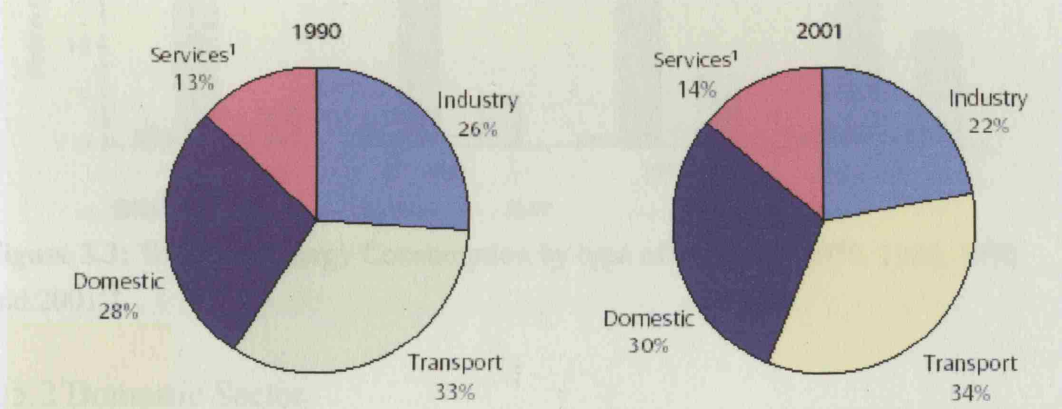

Figure 3.2: Percentage Sector Shares in Total Energy Consumption, 1990 and 2001[27].

3.5 Energy Consumption by Sectors

This session briefly describes where the final energy ended up in each sectors as this information is essential for policy maker to understand, in order to find an optimum solution to reduce carbon emission.

3.5.1 Transport Sector

Transport is a very important to everyone as many goods are transported over a long distance before they reach the shop. Also, modern-day transport provides people to travel to places that cannot be easily reached before. Transport energy consumption has increased by 95 percent since 1970 and by 13 percent since 1990. In 2001, *54,932* thousand tonnes of oil equivalent were consumed in the transport sector, three quarters of which was consumed for road transport. Figure 3.3 shows the increases in energy consumption by the transport sector over time. It also shows the increasing amount consumed for air transport, accounting for 21 percent of all energy consumed in the transport sector in 2001. Between 1990 and 2001, energy consumption increased by 56 percent in the air transport sector, by 8 per cent in the rail transport sector and by 7 percent in the road transport sector.

[27] Dti, **Energy Consumption in United Kingdom**. P.11

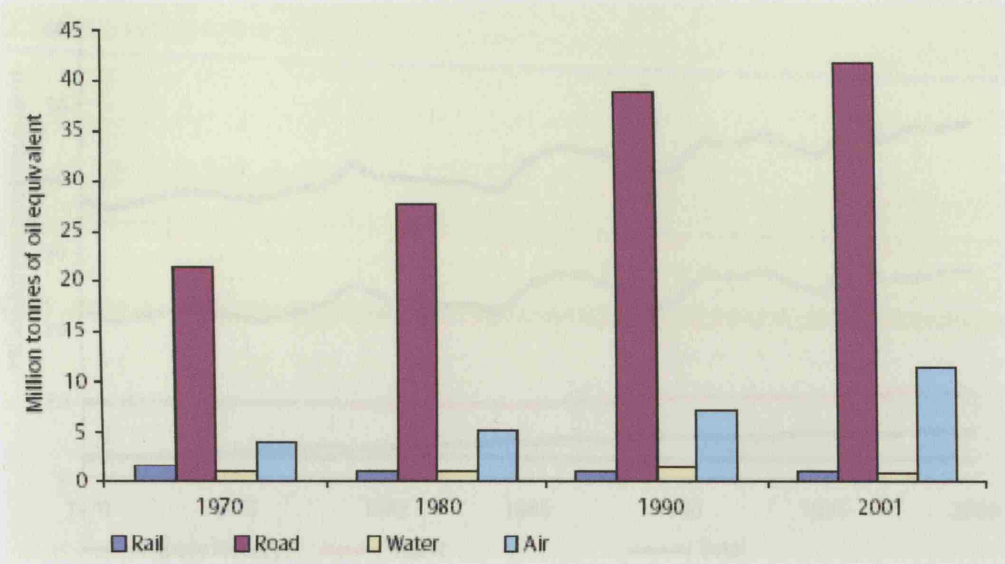

Figure 3.3: Transport Energy Consumption by type of transport, 1970, 1980, 1990 and 2001[28].

3.5.2 Domestic Sector

Domestic energy consumption has increased by 32 percent since 1970 and by 19 per cent since1990. One of the main reason of this increase is because of the rising number of population new household; since 1990 the number of households has increased by 10 per cent, population has increased by 4 per cent and household disposable income has increased by 30 per cent. Energy efficiency improvements, such as increased levels of insulation and the introduction of more efficient electrical appliances, have meant that domestic energy consumption has not increased at a greater rate. The majority of energy consumed in the domestic sector is for space heating, which accounted for 58 percent of all delivered energy consumed in 2000, as shown in Figure 3.4. Space heating is influenced by external temperature as indicated by the peak and trough in Figure 3.4 Between 1970 and 2000, energy consumption in lighting and appliances increased by 157 percent as technology became commonly available e.g. personal computer; while energy use in cooking has fallen by 16 per cent.

[28] Dti, **Energy Consumption in United Kingdom**. P.12

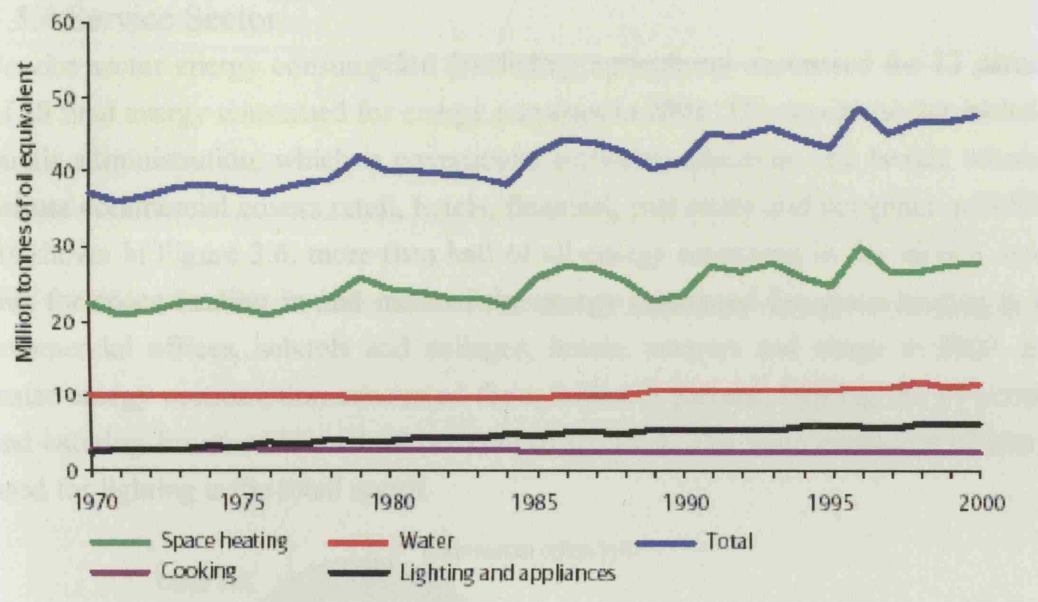

Figure 3.4: Domestic Final Energy Consumption by End Use, 1970 to 2000[29].

3.5.3 Industry Sector

Industrial energy consumption has fallen by 44 percent since 1970 and by 9 per cent since 1990; there was a slight increased by 2 percent since 1996.Industrial energy consumption accounted for more than a fifth of all UK energy consumption in 2001, consuming 35,152 thousand tonnes of oil equivalent. In 2001 the largest sub-sector was the chemicals industry, accounting for 22 percent of all industrial energy consumption.

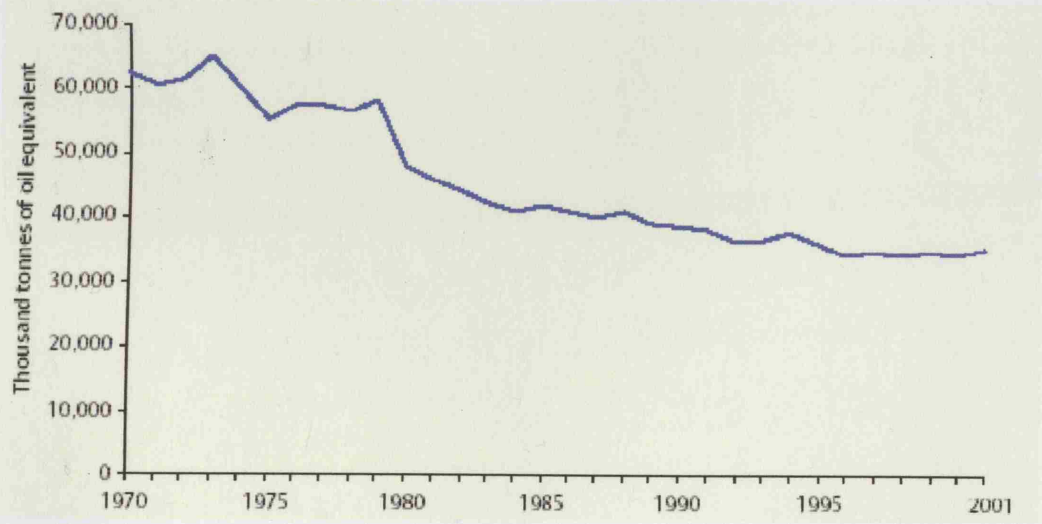

Figure 3.5: Total Industrial Energy Consumption[30]

[29] Dti, **Energy Consumption in United Kingdom**. P.23
[30] Dti, **Energy Consumption in United Kingdom**. P.30

3.5.4 Service Sector

Service sector energy consumption (excluding agriculture) accounted for 13 percent of all final energy consumed for energy purposes in 2001. The service sector includes public administration, which is government activities, education and health; whereas private commercial covers retail, hotels, financial, real estate and computer activities. As shown in Figure 3.6, more than half of all energy consumed in the service sector was for space heating in and most of the energy consumed for space heating is for commercial offices, schools and colleges, hotels, caterers and shops in 2000. Hot water energy consumption accounted for a further 9 percent, lighting for 14 percent and catering for an additional 10 per cent of the total. The main consumer of energy used for lighting is the retail sector.

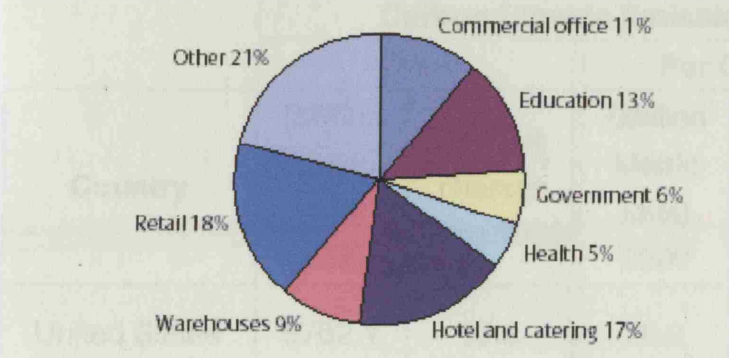

Figure 3.6: Service Sector Energy Consumption by sub-sector, 2000.[31]

[31] Dti, **Energy Consumption in United Kingdom**. P.37

3.6 Carbon Emissions

Table 3.1 and Figure 3.7 can easily explain the situation of UK in the carbon emissions problem. Being a developed country, UK has emitted far less carbon dioxide than other developed countries such as Japan and the US. But since the US is a bigger country in both area and population size, it is fairer to measure the mass of CO_2 produced per person for a country. The results have shown that UK and Japan have produced less than 10 MMT of CO_2 per capital, whereas the US has emitted 20.2 MMT per capital, doubled the result of UK and Japan. Bangladesh is the only developing country in this comparison and it has only produced a tiny fraction of CO_2 compared to other three developed countries.

	Carbon Dioxide Emissions			
	Total		Per Capital	
Country	(Million Metric tons) 2000	Percent change since 1990	(Million Metric tons) 2000	Percent change since 1990
United States	5762.1	17.9	20.2	5.8
Japan	1224.7	12.3	9.6	9.2
United Kingdom	558.2	-3.3	9.5	-6.4
Bangladesh	29.9	105.6	0.2	63.2

Table 3.1: Carbon Emissions[32]

[32] World Resources Institute, International Energy Agency, United Nations Framework Convention on Climate Change. **Climate and Atmosphere 2005**

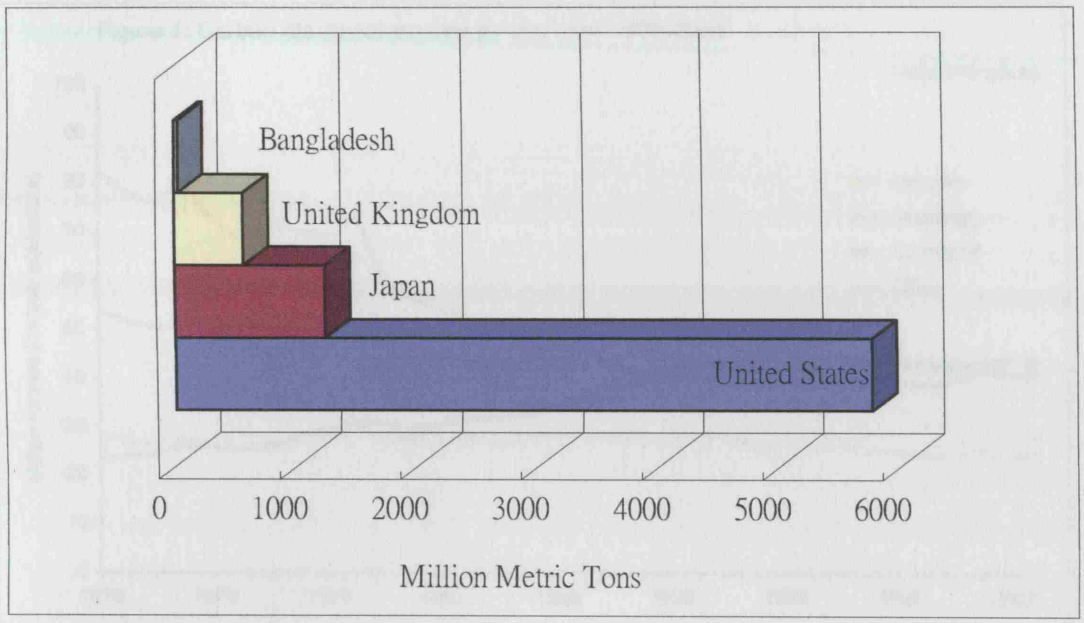

Figure 3.7: Carbon Dioxide Emission, 2000[9]

Carbon dioxide emissions in 2002 have reduced by 21% since 1970, as shown in Figure 3.8. However, this decline has not been steady, and peaks were observed in 1973 and 1979 which were due to the state of the economy, high oil prices and severe winters in these years. Emissions fell again during the early eighties reflecting the recession during this period and the coal miners strike of 1984. Since the mid-1980s the emissions profile has been much smoother showing an overall reduction in emissions. There are small increases in several sectors. The elevated emission from the domestic sector in 1996 is considered to be due to the colder than average winter, this is the same reason as described in chapter 3.5.2.

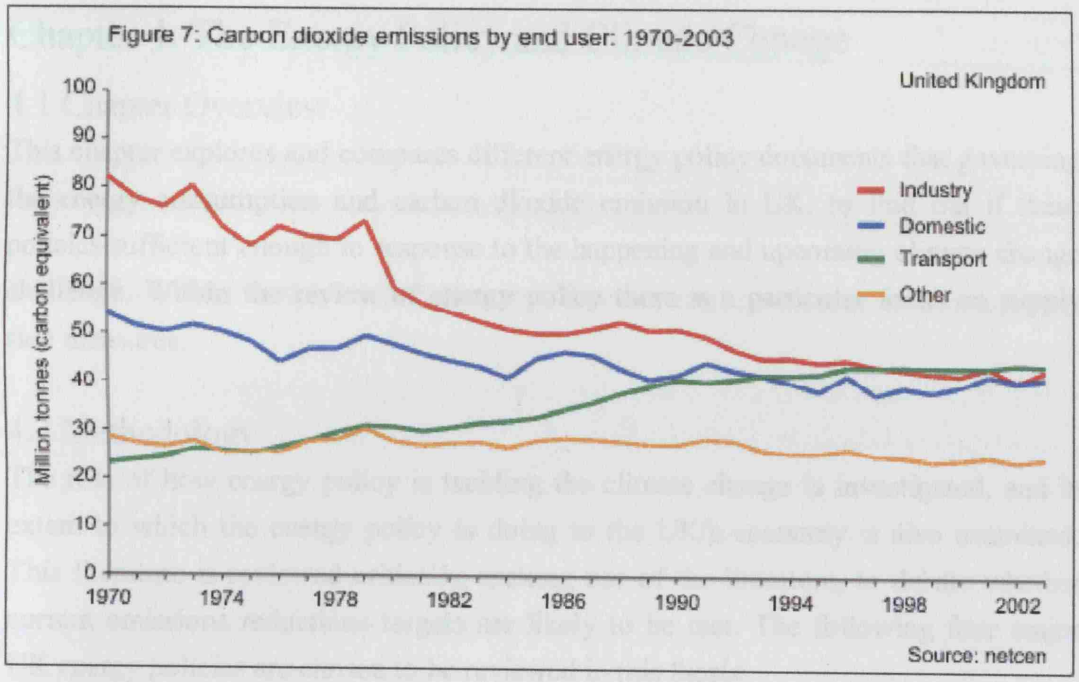

Figure 3.8: Carbon Dioxide Emissions by end user, 1970 to 2003[33]

3.7 Summary and Conclusion

Energy consumption in the UK is rising and it is in all time high at present. UK is burning so much oil, gas and coal but is consuming very little renewables. For the economy as a whole, the trend of fuel type has changed from using coal to nuclear and gas. There is an urgent need to develop new technology on renewables and encourage more use of renewables across the sectors. The trend of energy consumption in the UK has shifted from industry sector towards the domestic and service sectors. Both domestic and service sectors use energy mainly on space heating and hot water. As for the carbon dioxide emission in UK, the figure shows that it has fallen since 1970 and appears to be one of the key countries to meet its Kyoto targets. However, the data shown does not include airline emission. If airline emission is taken into account, there is no sign of falling since 1990 as the largest increase has been from air transport, which has nearly tripled since 1970. To conclude, these are the problems the government should tackle when energy policy and regulation is made. In the next chapter, four energy policy documents will be reviewed and see if the government has paid attention to reduce energy consumption in these areas.

[33] Defra, http://www.defra.gov.uk/environment/statistics/globatmos/kf/gakf07.htm

Chapter 4: The Energy Policy and Climate Change

4.1 Chapter Overview

This chapter explores and compares different energy policy documents that governing the energy consumption and carbon dioxide emission in UK, to find out if these policies sufficient enough to response to the happening and upcoming climate change challenge. Within the review of energy policy there is a particular focus on supply side measures.

4.2 Methodology

The role of how energy policy is tackling the climate change is investigated, and in extent to which the energy policy is doing to the UK's economy is also examined. This literature is reviewed critically, making use of the literature, to debate whether current emissions reductions targets are likely to be met. The following four major UK energy policies are chosen to be reviewed in this thesis:

- **UK Energy White Paper**
- **Climate Change Levy and UK Emissions Trading Scheme**
- **Energy Efficiency Commitment**
- **Renewable Obligation**

4.3 UK Energy White Paper

4.3.1 Introduction

On 24 March 2003, in order to meet future challenges, the UK government published its long-awaited 'Energy White Paper', which details the government's new energy policy to ensure that 'energy, the environment and economic growth are properly and sustainably integrated'.

The White Paper puts forward plans to avoid over-dependence on imported energy by developing renewable energy sources within the UK.

UK Prime Minister Tony Blair states that 'We are showing leadership by putting the UK on a path to a 60% reduction in its carbon dioxide emissions by 2050'. But, is this a realistic goals or being too optimistic? Answer to this question is needed to be found in this chapter.

There are four main goals for the government's new energy policy:

- cutting carbon dioxide emissions
- maintaining the reliability of energy supplies
- promoting "competitive markets in the UK and beyond"
- ensuring that every home is adequately and affordably heated

4.3.2 Discussion on the UK Energy White Paper

The UK Energy White Paper is the first major energy policy published for many years. This policy encompasses both supply and demand side issues. The supply side issues include the future of nuclear, support for the coal industry, renewable energy policy, and liberalisation and regulation of the privatised energy industries. Demand side issues include energy efficiency, household-level renewables and combined heat and power schemes. Since there are many issues covered in the Energy White Paper, only the important concern is being discussed.

Goal 1: Cutting carbon dioxide emissions

The first goal of the white paper is to tackle greenhouse effect and climate change. This is put as the first goal to demonstrate that this is the core problem needed to be tackled. This white paper is the first step to achieve the 60% cut in emission by 2050 and can be seen as the MASTER PLAN of all the other energy policy. Year 2050 seems a distance away from year 2005, but action has to been taken now to achieve the first goal, a low carbon economy. This is because in an organisation, a big change does not come in a short time as business organisation tends to remain 'status quo' and afraid of sudden change. The Energy White Paper certainly makes this organisation to operate very differently from now. Therefore, the white paper provides an early warming and plenty of time to the organisation to adopt, adjust and act upon the white paper policy gradually and steadily.

The Energy White Paper has chosen "in the home", "at work" and "in the public sector" as the main areas that saving can be made.

In the home, each gas and electricity supplier has an energy target to meet for **Energy Efficiency Commitment (EEC). EEC** is the current obligation on gas and electricity retailers to achieve energy savings. This scheme runs from April 2004 to 2005. This scheme is welcomed by energy supplier and a new EEC starts from April 2005 to April 2008, looking at twice the level of activity. This makes the energy supplier to integral as part of their long term business strategies. The EEC's energy target can add a new topic to discuss apart from "Profit and Losses" in the annual board meeting within the energy suppliers themselves, to make EEC as part of the

operation, not project. This is a good approach as these energy suppliers have targets to meet and they try very hard by improving householders' energy saving measures such as subsidising the cost of installing a condensing boiler and energy efficient appliances etc. The end results are "WIN WIN" situation. Firstly, the energy supplier meets their targets. Secondly, the customer benefits from the energy bill savings and more comfortable home. Finally, carbon saving can be made out of this.

The Energy White Paper promotes energy efficiency as the key to cut down 15-25MtC[34] by 2020, combined with increasing use of renewables and EU carbon trading scheme, as shown in Table 4.1. In 2004, a follow up document "Energy efficiency: the government's plan for action" has been produced. This document explains how promoting energy efficiency can contribute to achieve the goals set in UK energy policy and the carbon cut down in each sector. Table 4.2 shows a cut of 4.2MtC can be achieved in domestic sector in 2010, this is less than 5MtC suggested in the Energy White Paper. But if this rate remains, the target set in the Energy White Paper of 4-6MtC cut in domestic sector by 2020 is still achievable.

	Estimated MtC reductions[8]
Energy efficiency in households	4-6
Energy efficiency in industry, commerce and the public sector	4-6
Transport: continuing voluntary agreements on vehicles; use of biofuels for road transport	2-4
Increasing renewables	3-5
EU carbon trading scheme	2-4

Table 4.1: How Cuts of 15-25MtC could be achieved by 202035

[34] Million metric tons of carbon
[35] Dti, Energy White Paper, p.26

Households	Projected Carbon savings (MtC pa)
Measures already in the UK Climate Change Programme	1.5
Energy Efficiency Commitment from 2005, Decent Homes*	1.4
Warm Front	0.2
Community Energy	0.1
Building Regulations 2005	0.8
Other measures	0.2
	4.2

Table 4.2: How Cuts of 4.2 MtC could be achieved in Domestic by 2010[36]

From Table 4.2, a huge saving of 1.4 MtC comes from **Energy Efficiency Commitment (EEC), Decent home.**

Another key policy on carbon reduction is the new Part L of the National Building Regulations. The influence of Part L has been increasing in recent years e.g. in 2002, it starts to govern the efficiency of replacement windows in existing buildings and not just controls new housing anymore.

At work, climate change levy (CCL) is in place to encourage energy efficiency in business. CCL is discussed in Chapter 4.5. An EEC approach to business that does not pay the CCL to enhance the energy efficiency further and this idea is under consultation.

In the public sector, there is actually no more than 5% of UK carbon dioxide contribution. But, this sector is very important especially the government itself, to lead others by role model. The Energy White Paper has illustrated that the NHS Trusts have already targeted to reduce 0.15 MtC from March 2000 to March 2010. This sounds like a promising start by the government itself but why the government has not done anything (e.g. to be a role model) earlier than now (or before they signed up the Kyoto Protocol). It is for sure that the government has known about the problem of energy (e.g. energy price and carbon emission) is going to affect UK's economy sooner or later. Also, there is a lesson learnt before climate change, this is the energy crisis in mid 1970s. If as the government suggested, "Energy Efficiency" alone is enough to cut down energy consumption, the government should have promoted across the sectors after energy crisis in mid 1970s, as one of the solution to relieve and prevent energy crisis to happen again.

Renewable energy allows new energy sources and low or no carbon generation technologies. Renewables play a crucial part and there is great potential to implement

[36] DEFRA, Energy Efficiency: The Government's Plan for Action, p.11.

this. UK needs to generate at least 30% to 40% of electricity out of renewables to achieve the 60% carbon emission by 2050. The government approach to renewables is discussed in chapter 4.6.

Goal 2: Maintaining the reliability of energy supplies

The second goal is important to everyone to maintain the quality of life and the UK economy. This goal is to demonstrate that, even the carbon emission is cut down, the constant, reliable, high-quality supply of energy will remain the same. But there is still plenty of work to be done to achieve this goal. The paper states that the first strategy towards energy reliability as a whole is by "energy efficiency" to reduce the demand of energy. As discussed before, the promotion of "energy efficiency" is still in trial phase and there are still a lot of variables to be adjusted. The monitoring of energy reliability becomes the high priority from 'now' and Ofgem[37] has agreed that 'in future' it will report on how its regulatory activities impact on energy security. It shows that this is not happening and still under consultation.

The energy reliability is divided into short term issues and long term issues. Short term issues include major technical problems and extreme weather conditions and terrorism. The Government and Ofgem have planned to set licence conditions on industry participants and the price reviews of the monopoly infrastructure providers. This set condition with the privatised power companies is necessary as they have not been investing in new plant or infrastructure because they see their profit margins being squeezed. Instead, they are shutting down plants that they think as excess capacity to main their profit. This licence conditions can help to secure UK stable energy supply. As discussed before, the climate is changing in UK and resulting in more unpredictable weather and there is a high surge in demand for power.

UK has been a net exporter because of the successful development of North Sea[38]. But there are forecasts showing UK will become a net energy importer rather than exporter over next two decades. The long term plan is to secure sufficiently diverse fossil fuel sources as The Energy White Paper states an international strategic approach to energy approach is necessary. The first approach is to buy and obtain the gas and oil from more international sources. The second approach is to keep and enable the globe oil and gas suppliers to trade freely, so that UK can purchase what it requires at any time. The principle is based on producers and consumers have a common interest in ensuring effective trade in energy products in stable markets. This

[37] Ofgem (the office of gas and electricity market) is the regulator for Britain's gas and electricity industries.

[38] oil was discovered under the North Sea in 1970

paper addresses that the UK foreign policy plays an important part, FCO[39] will work more closely with other government departments to achieve common objectives in international energy security. This is very difficult for national government to influence international issue and this policy push beyond traditional of energy policy. Within the UK itself, there are three departments are involved to monitor the energy security issue, they are the Ofgem, FCO and Dti; where Dti and Ofgem have formed JESS, "the Dti/Ofgem Joint Energy Security of Supply Working Group". One key problem these departments have to be aware of is the 'communication' between them. A sophisticated communication system has to be set up so that they can react to situation more efficiently.

These strategies are very crucial to the UK energy security. If the strategies are working well in the future, even UK will become a net importer of gas and oil in the next decade, these strategies ensure UK can keep generating energy locally and just the raw material is sourced from import. This is better than the energy is depended on foreign grids. The 2003 crisis in Italy and Denmark highlighted its chronic dependency on foreign sources of energy. Italy draws in power from France and Switzerland, also from Austria, Slovenia and Greece via an underwater cable. On a Sunday in Italy more than 55 million people were plunged into darkness - at least five million more than in the power cuts which hit the eastern US and Canada last month[40]. Some parts of the south were without electricity for 18 hours. This leads to a parliament debate on re-open nuclear plants in Italy, which this is against by environmentalist. Massive power cuts in Denmark in late September 2003 were caused by damage to the power transmission lines linking Sweden and Denmark, from where Denmark obtains much of its power. This trans-boundary dependency for energy is increasing the risk of political, physical and economic insecurity. UK government has made a correct decision for the UK energy security, although there is plan needed to be implemented.

[39] Foreign and Commonwealth Office
[40] The Guardian, http://www.guardian.co.uk/international/story/0,,1052262,00.html#article_continue

Goal 3: Promoting "competitive markets in the UK and beyond"

The third goal is to ensure the economy grows with the new way of energy use. Note that only the main strategy related to energy is discussed here and please refer to the 'Energy White Paper' for more detail. According to the white paper, UK government set the regulatory framework by introducing NETA[41] in 2001. NETA is designed to bring better wholesale electricity trading and promote more direct competition, as vigorous competition improves efficiency and drives down prices. The traded wholesale electricity is 40% lower than in 1998. The UK government promised that to invest an extra £60m on energy research, development and innovation. Also, Energy Research Review Group (ERRG) suggested there is a need for further research on social and economic factors. It is good to see that these plans are designed in both enterprise and consumer/customer prospective. Moreover, there are lots of actions, that working in parallel to achieve this goal. This goal is reachable if everything is pull together well.

Goal 4: Ensuring that every home is adequately and affordably heated

The final goal is to make sure the cost to use energy remains in an affordable level. In social aspect, this goal makes sure both poor and rich can heat up their home in the same degree, no discrimination i.e. equal treatment. The UK government tackles the fuel poverty factors one by one, these are the energy efficiency of the home, fuel costs and household income. *'The UK Fuel Poverty Strategy'* published in November 2001 is responsible for the policy that can end fuel poverty. Apart from this policy document, the UK government is running a number of grunt schemes to support the eradicating fuel poverty sustainably. These schemes are the 'Warm Front' in England, 'Warm Deal and the Central Heating Program' in Scotland, 'the New Home Energy Efficiency Scheme' in Wales and 'Warm Homes' in Northern Ireland. In addition, UK has established the Fuel Poverty Advisory Group in England and a similar group works with the Scottish Executive on progress in tackling fuel poverty in Scotland. Their task can be summarised as to monitor and control the progress against fuel poverty targets annually. Furthermore, houses tend to be older, less energy efficiency and harder to heat in the countryside. In many cases, the houses in rural areas do not have access to mains gas, oil fuel, electric heating or liquefied petroleum gas (LGP). Therefore, Dti is working with Transco[42] to expand the gas network to this area. The UK government aim is to end fuel poverty by 2016 to 2018, in less than 20 years time. This problem is very likely to resolve as there are already plans to improve energy efficiency to home and reduce fuel costs mentioned in the other section of the white

[41] **New Electricity Trading Arrangements**

[42] **Transco** is a gas transporter. It transports and stores gas for its customers through a transportation network across the UK.

paper and various document e.g. Building Regulation were amended recently to raise the energy efficiency standards for central heating boilers. Also, there are grant schemes running across the country. Not only that, the aim is clear and the strategy it set out is simple but yet effective, in term of time and cost.

4.4 Energy Efficiency Commitment (EEC)

4.4.1 Introduction

This Government scheme, which is administered by Ofgem, sets each electricity and gas supplier a target to save energy based on the number of domestic customers they supply. The scheme has an environmental aim, providing carbon savings under the Climate Change program, as well as social focus, with half of the energy savings to be targeted at the' priority group', through this, the EEC also contribute to the Government's Fuel Poverty Strategy. Suppliers encourage and assist their domestic consumers to make energy savings, through installing measures described in table 4.3. At least 50% of energy savings must be focussed on low-income consumers, specifically those in receipt of certain benefits and tax credits/pension credit.

Lighting	CFLs (stick CFLs and decorative bulbs) Luminaires (dedicated CFL fittings)
Insulation	Cavity wall insulation Loft insulation Solid wall insulation Draught-proofing Hot water tank insulation Radiator panels
Heating	Boilers Boilers with heating controls Solar water heating
Appliances	Cold appliances (fridges and freezers) Wet appliances (dishwashers and washing machines)

Table 4.3: The Energy Efficient Measures[43]

[43] **EEC Update Issue 1,** August 2002.
http://www.ofgem.gov.uk/temp/ofgem/cache/cmsattach/124_9aug02_pub.pdf?wtfrom=/ofgem/work/index.jsp&section=/areasofwork/energyefficiency

Defra is responsible for setting the overall energy saving target as describes below:

- 62 TWh[44] for the EEC 2002 to 2005 (EEC1)
- 130 TWh for the EEC 2005 to 2008 (EEC 2)

4.4.2 Discussion on EEC

According to the review of the Energy Efficiency Commitment 2002-05[45], the first phase of EEC required energy suppliers to achieve a total energy saving of 62TWh in the domestic sector. Half of the savings were to be made in 'priority group' households. All suppliers met their targets and a total of 86.8TWh were saved during the three years of the scheme. The excess savings have been carried over to the second phase of the scheme, which runs from April 2005 to March 2008 and requires a total saving of 130TWh of energy. Ofgem estimates that the savings made in the first phase of the scheme resulted in a saving of £350 million per year over the lifetime of the measures, which is an average of £35 per household. £175 Million of these were made in the priority group. The main findings of the report on phase one of the EEC show that:

- 56% of the total savings were made through insulation measures, benefiting over one million households
- 9% of the total savings were made through heating measures, more than 300,000 energy-efficient boilers were installed
- 11% of the total savings were made through subsidised, energy efficient appliances, of which customers bought 6.5 million
- 25% of the total savings were made through almost 40 million energy-efficient light bulbs being supplied to customers.

The result of phase one has proved that the EEC scheme is a big success and the suppliers should be full of confidence to achieve the target set in phase two. The EEC has helped the government a lot, to achieve their forth goal described in the Energy White Paper. EEC has shown a steady progress and more work should be built upon this success. This scheme should be kept going even if the target in phase two cannot be achieved in future, since it proved to have a very direct effect on improving the living standard of household with low income and encourages the suppliers to carry out more energy efficient installation in the domestic sector.

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[44] Terawatt hour

[45] http://www.ofgem.gov.uk/temp/ofgem/cache/cmsattach/12015_18105.pdf

4.5 Climate Change Levy (CCL) and UK Emission Trading Scheme

4.5.1 Introduction

CCL

The climate change levy[46] is a tax on the use of energy in industry, commerce and the public sector (please refer to *Appendix 1* for the list of eligible sectors), with offsetting cuts in employers' National Insurance Contributions (NICs) and additional support for energy efficiency schemes and renewable sources of energy. The levy forms a key part of the Government's overall Climate Change Programme. The basic design of the levy follows the recommendations made in Lord Marshall's report *Economic Instruments and the Business Use of Energy*, published in October 1998.

The levy was introduced on 1st April 2001. It was announced in the March 1999 Budget to give businesses a full two years time to adjust. Rates of levy are 0.15p/kWh for gas, 1.17p/kg (equivalent to 0.15p/kWh) for coal, 0.96p/kg (equivalent to 0.07p/kWh) for liquefied petroleum gas (LPG), and 0.43p/kWh for electricity. The levy is expected to raise around £1 billion in its first full year (2001/02). The levy package is also expected to lead to reductions in carbon dioxide emissions of at least 2.5 million tonnes of carbon a year by 2010.

The levy does **not** apply to fuels used by the domestic or transport sector, or fuels used for the production of other forms of energy (e.g. electricity generation) or for non-energy purposes. The levy does not apply to energy used by registered charities for non-business uses, and energy used by very small firms, i.e. those using a *de minimis* (domestic) amount of energy.
The levy does *not* apply to oils, which are already subject to excise duty.
There are also several exemptions from the levy, including:

- Electricity generated from new renewable energy (e.g. solar and wind power)
- Fuel used by good quality combined heat and power schemes ("Good Quality CHP" - certified via the CHP Quality Assurance Programme CHP*QA*)
- Fuels used as a feedstock
- Electricity used in electrolysis processes, for example, the chlor-alkali process, or primary aluminium smelting

[46] Defra. http://www.defra.gov.uk/environment/ccl/index.htm

UK Emissions Trading Scheme

The UK emissions trading scheme is the world's first economy-wide greenhouse gas emissions trading scheme. This is a voluntary scheme and organisation signed up to CCL is also eligible. Companies meeting their emission reduction targets will receive 80% discount from CCL. Also, these companies can use this scheme either to buy allowances to meet their targets or sell any over-achievement of these targets.

In 2002, the Direct Participants achieved emission reductions of 4.64 million tonnes CO2e[47] against their baselines and in the second year (2003) they achieved emission reductions of nearly 5.2 million tonnes CO2e against their baselines. In 2004, there is a reduction of almost 6 million tonnes CO2e (5.9 million tonnes CO2e) was achieved by direct participants against their baselines in the 2004 compliance period.

4.5.2 Discussion on CCL and UK Emission Trading Scheme

The levy has played a major role in helping the UK to meet its targets for reducing greenhouse gas emissions. It entails no increase in the tax burden on industry as a whole and no net gain for the public finances. The reforms are intended to promote energy efficiency, encourage employment opportunities and stimulate investment in new technologies. It can be seen that the CCL is a very effective way to achieve the government's legally-binding target of a 12.5% reduction in greenhouse gas emissions, (set in Kyoto Protocol) and for moving towards the Government's domestic goal of a 20% reduction in carbon dioxide emissions. Carbon dioxide equivalent industry plays a very important role in climate change as mentioned earlier. If there is not regulation to improve the carbon emission situation, the government is bounded to miss the carbon emission target. The UK emission trading scheme works in conjunction with the CCL has given a promising effect, both environmentally and economically. It established UK as a leading trading centre. And taxation is a very good way to deal with non-domestic sectors, as this sector's primary goal is to earn money and make profit, to keep flow out of money to minimum where possible. In order for a company to stay in the game, one has to invest to reduce carbon emission to entitle for the tax reduction, like others to stay competitive, to reach the goal of sustainable economy growth in the future.

[47] carbon dioxide equivalent

4.6 Renewables Obligation (RO)

4.6.1 Introduction

The Renewables Obligation (RO) was developed as a direct incentive to encourage new builds in renewables generation in the UK. The RO places a mandatory requirement for UK electricity suppliers to source a growing percentage of electricity from eligible renewable generation capacity by15 percent by 2015. The eligible sources are listed in the Appendix 2.Suppliers are required to produce evidence of their compliance with this obligation to the Office of Gas and Electricity Markets (Ofgem). Evidence can be via certificates, referred to as Renewable Obligations Certificates (ROCs). Each ROC represents one megawatt hour (1,000,000 units) of electricity generated from eligible sources Suppliers can meet their obligation by:

- acquiring ROCs
- paying a buy-out price of £30/megawatt hour
- a combination of ROCs and paying a buy-out price.

4.6.2 Discussion on RO

Period	Estimated sales by licensed suppliers in UK	Actual sales by licensed suppliers in UK	Total Obligation (UK) is based on (a)	Total Obligation as a percentage of sales (UK) is based on (a)
	(a) terawatt hours	(b) terawatt hours	(c) terawatt hours	(d) %
2001/02	310.9	318.35		
2002/03	313.6	319.42	9.4	3
2003/04	316.2	328.36	13.5	4.3
2004/05	318.7	330.13	15.6	4.9
2005/06	320.6		17.7	5.5
2006/07	321.4		21.5	6.7
2007/08	322.2		25.4	7.9
2008/09	323		29.4	9.1
2009/10	323.8		31.5	9.7
2010/11	324.3		33.6	10.4

Table 4.4: Obligation Level[48]

[48] Dti. http://www.dti.gov.uk/renewables/renew_2.2.1.htm

Table 4.4 has shown the obligation as a percentage has risen from 4.3 percents in 2003 to 4.9 percents in 2004 and percentage is predicted to continue to rise. Changes has been made after consultation in 2004 and already come into effect on April 2005. The target of reaching 15 percent by 2015 sounds very promising. Having regulation on encouraging the use of renewables is very important, RO has made a great step towards a sustainable energy future. RO has proved an effective means of promoting the exploitation of mature renewables. The RO has been successful in promoting the cheapest and most established renewable technologies. This is most evident in the substantial volume of applications for onshore wind projects. The RO is effective in stimulating investment, as attested by the large volume of applications for connection of new wind generation. Developing new renewables technology also helps UK to achieve the goal of energy security.

The downside of RO is the sudden change in the use of renewable energy policy, it is being implanted too fast. The progress of the RO needs to be continuously monitored, such as the market, planning and social factors, to achieve a smooth long-term transition.

4.7 Summary and Conclusion

Increasing numbers of documents and reports are published in conjunction to the UK energy white paper. The documents reviewed here is just a small friction. The level of work to achieve the white paper goals are getting more complex, as one has to refer to different documents and the policy is kept updating. (UK energy policy change, other Industrial Guide book has to change with this). Renewable is the next big movement in energy, but more work has to be done in the RO and the government has been kept consulting and made progressive changes. Table 4.5 summarised the objective of the four energy policies. Table 4.6 summarised the sectors that are affected by the energy policies.

Energy Policy	What is the policy objective?						
	Improve Energy Efficiency	Reduce Carbon Emission	Promote Energy Security	Improve Rural Economy	Promote New Technologies	Promote UK Industry	Alleviate Fuel Poverty
UK Energy White Paper	■	■	■	■	■	■	■
Energy Efficiency Commitment	■	■					■
Climate Change Levy	■	■					
Renewable Obligation		■	■	■	■	■	

Table 4.5: The Main Objective of the Listed Energy Policy.

Energy Policy	Who does the policy affect?							
	All Sectors	Industry	Energy-intensive Industry	Public Sector	Commerce	Domestic	Transport	Energy Provider
UK Energy White Paper								
Energy Efficiency Commitment								
Climate Change Levy								
Renewables Obligation								Electricity Supplier
Legends:								
Fully Affected								
Partially Affected								

Table 4.6: The Sectors Affected by the Listed Energy Policy.

A report entitled *Renewable Energy*[49], published recently by the National Audit Office analysed the cost of various policies to reduce carbon emissions as shown in Table 4.7.

Policy	Cost (£/tonne CO2)
Energy Efficiency Commitment	-16
Climate Change Levy	5 to 11
UK Emissions Trading Scheme	18
Renewables Obligation	70 to 140

Table 4.7: Cost of Different Policies to Reduce Carbon Dioxide Emissions

[49] Association of the Conservation of Energy, **Review of the Climate Change Program,** http://www.ukace.org/pubs/consult/Defra%20Review%20of%20UK%20Climate%20Change%20Programme%20(ACE%20response).pdf

Chapter 5: Macro-scale Energy Model

5.1 Chapter Overview

The various UK energy policy documents discussed in chapter 4 are all set out to achieve a long-term policy goal, but no one can guarantee the ideal targets described in those policies are 100 percent achievable. There is always contradiction as discussed in chapter 4. And this is where modelling and simulation comes in to play. A useful model would give accurate forecasts and calculate the feasibility of a policy. This chapter examines two recognisable energy models, 'Markal' and 'E3ME', first to describe the natural of these models and the modelling work has been carried. These models focus on climate change and the economic costs of environmental policies. The question of 'What are the impacts of currently proposed environmental policies in UK on economic growth in the 21st century?' hopefully can be answered by looking at this modelling work.

5.2 Markal Model

MARKAL was developed by the Energy Technology Systems Analysis Programme (ETSAP) of the International Energy Agency; it is a generic model tailored by the input data to represent the evolution over a period of usually 40 to 50 years of a specific energy system at the national, regional, state or province, or community level[50]. MARKAL is a bottom-up technology model of the energy system. Bottom-up models focus on the activities of the people who deal with energy consumption and production, plus the changes in technologies. Based on detailed descriptions of these items, they calculate the total energy consumption and production from the 'bottom-up'.

The basic components in a MARKAL model are specific types of energy or emission control technology. Each is represented quantitatively by a set of performance and cost characteristics. A menu of both existing and future technologies is input to the model. Both the supply and demand sides are integrated, so that one side responds automatically to changes in the other. The model selects that combination of technologies that minimizes total energy system cost.

[50] ETSAP. http://www.etsap.org/markal/main.html

5.2.1 Markal Modelling Work on UK Energy White Paper

The UK Energy White Paper has used the Markal as the analytical tool. Markal model has been applied to the following four situations:

- work commissioned from Future Energy Solutions using the MARKAL energy model to consider the options and costs of achieving long-term reductions in CO_2 emissions;
- consideration of the system costs attached to increasing levels of electricity generation from renewables from 10% to 20 or 30%;
- a review of the evidence in relation to the type and scale of ancillary effects (such as impacts on air quality) that may accompany reduction in greenhouse gas emissions;
- consideration of issues attached to security of gas and electricity markets, of the barriers to the operation of competitive markets that might lead to inadequate of costly provision of security, and the scale of such potential impact;

5.2.2 Key Findings from Markal Modelling

The White Paper Modelling[51] document provided by Dti, Markal analysis is based on technology availability and costs assumptions, which are reflected expert opinion, informed by workshops with industry experts. Markal model suggested that it will costs £200-300 per tonnes of carbon to achieve the 60% carbon reduction target by 2050. In terms of GDP[52], it is of the order of 0.5-2% (between £10-50bn) in 2050, compared with a forecast level of GDP in 2050 of around £2500bn. This is equal to a reduction of between 0.01 and 0.02 percentages in the average GDP growth rate over the period between 2000 and 2050. Also, some of the industrial and UK regions are mostly affected by the forecasted higher energy prices, according to Markal model. These sectors include chemicals, man-made fibers, paper, iron and steel. The regional areas will be affected the most are in Wales, the North East, Yorkshire and the Humber and the North West. More over, the energy costs as a share of GDP decline over the period to 2050, notwithstanding the costs of low carbon measures. On the cost assumptions made, a range of technology options become available to reduce CO_2 emissions. Innovation is important in reducing costs. The model runs showing the highest costs were those in which either the level of innovation in new and existing low carbon technologies was limited or where nuclear and carbon capture and storage were completely excluded combined with limits on improvements in energy efficiency. The share of renewables in electricity generation increases to between 25%

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[51] White Paper Modelling. http://www.dti.gov.uk/energy/whitepaper/wp_mod.pdf

[52] Gross Domestic Product is defined as the total value of all and the common equation for GDP is: GDP = consumption + investment + exports - imports.

and 40% by 2050. If new nuclear build and carbon sequestration are excluded, more renewables are required of in order to meet the carbon dioxide constraint. Energy efficiency improvements are required to provide a substantial contribution to meeting reduction targets at low cost. The cost to reduce CO_2 in the transport sector is relatively high. In the absence of future carbon constraints, fossil fuel use continues to dominate. In the constrained CO_2 runs, the transport sector moves significantly into hydrogen fuel cells after 2030 or in some cases after 2040. In general, the costs of many of the lower carbon technologies are fairly close.

5.3 E3ME Model

The E3ME (Energy-Environment-Economy Model for Europe) model has been built by a European team under the EU JOULE-THERMIE[53] programme as a framework for assessing energy-environment-economy issues and policies. The model has been used for general macro analysis and for more focused analysis of policies relating to greenhouse gas mitigation, incentives for industrial energy efficiency and sustainable household consumption. Also, E3ME is intended to meet an expressed need by researchers and policy makers for a framework for analysing the implications of long-term E3 policies, especially those concerning Research & Development and environmental taxation and regulation.

5.3.1 E3ME Findings of the Government's Targets on Climate Change in 1999[54]

In 1999, the research carried by **Cambridge Econometrics** has suggested that the Government's target of reducing carbon dioxide emissions by 20% from 1990's level by 2010 can be met. This target is met by combining five major sets of policies for carbon reduction:

- an increase in the proportion of electricity generated from renewable energy sources to 15% by 2010
- an increase in the capacity of combined heat and power (CHP) to 10 GWe by 2010
- a major programme of investment in domestic energy efficiency

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[53] European Commission's JOULE-THERMIE Programme in the field of non-nuclear energy is to improve energy security and reduce the impact of the production and use of energy, in particular CO2 emissions.

[54] **The 20% Solution: Meeting the government's target on climate change**. by Paul Ekins, Cathy Hough and Andy Russell of Forum for the Future, and Clare Bryden and Charlie Hargreaves of Cambridge Econometrics, Policy Briefing PB4/99, November 1999.

- a carbon tax on the business use of energy similar in size to the *proposed* Climate Change Levy
- and a continuation to 2010 in the annual increase in road fuel duty.

It would save the lives of thousands of people who would otherwise have died through not being able to keep warm (this coincides the 4th goal of the 'Energy White Paper'. It would also create a dynamic UK renewable energy industry; an economic sector which many forecasters believe will be among the fastest growing in the new century. On the negative side, the study finds that the policy package will reduce average UK economic growth from 2.56% to 2.54% per annum over 2000-2010, leading to a reduction in UK GDP by 2010 of 0.3%.

5.3.2 E3ME Findings of the Government's Targets on Climate Change in 2005[55]

In 2005, **Cambridge Econometrics** has indicated that the Government is set to **miss** its 20% carbon-reduction goal by 2010 by a wide margin. This opposes the research result released in 1999. The projected fall in carbon emissions over 2005-10 will not be enough to meet the Government's domestic policy aim of a 20% reduction in carbon emissions from the 1990 level by 2010

Cambridge Econometrics forecast indicates that CO_2 emissions are likely to be 12 percent below the 1990 level by 2010. Figure 5.1 makes a comparison with the domestic policy goal, restated in the Climate Change Program Review, of a 20% reduction.

[55] **Cambridge Econometrics Press Release Monday 09 May 2005**
http://www.camecon.com/whatsnew/releases/pdffiles/UKE3051.pdf

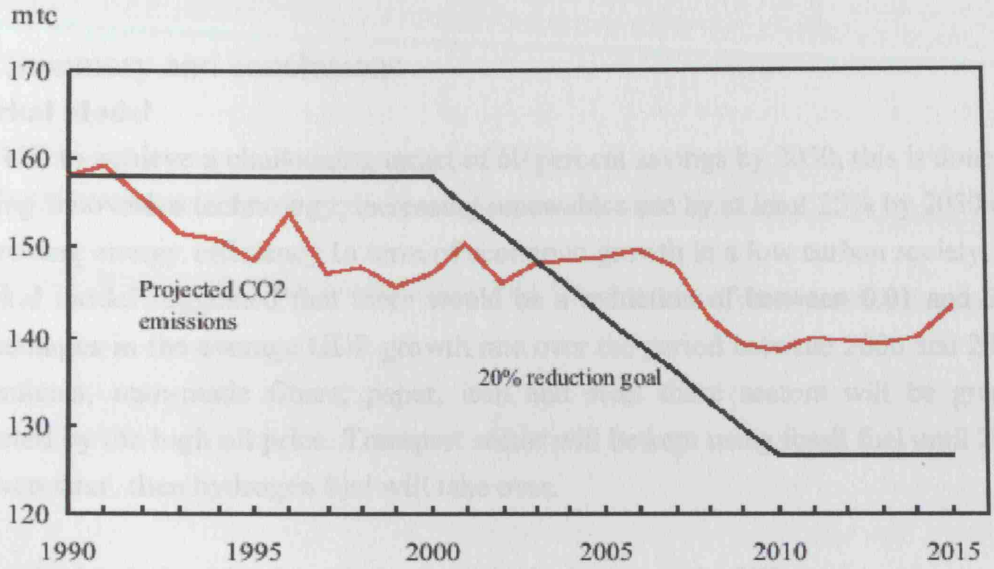

Figure 5.1: Compliance with Domestic Policy Goal[56]

Although the UK goal will not be met, the UK is forecasted to be on its path to achieve the Kyoto target for Greenhouse Gases, as shown in Figure 5.2.

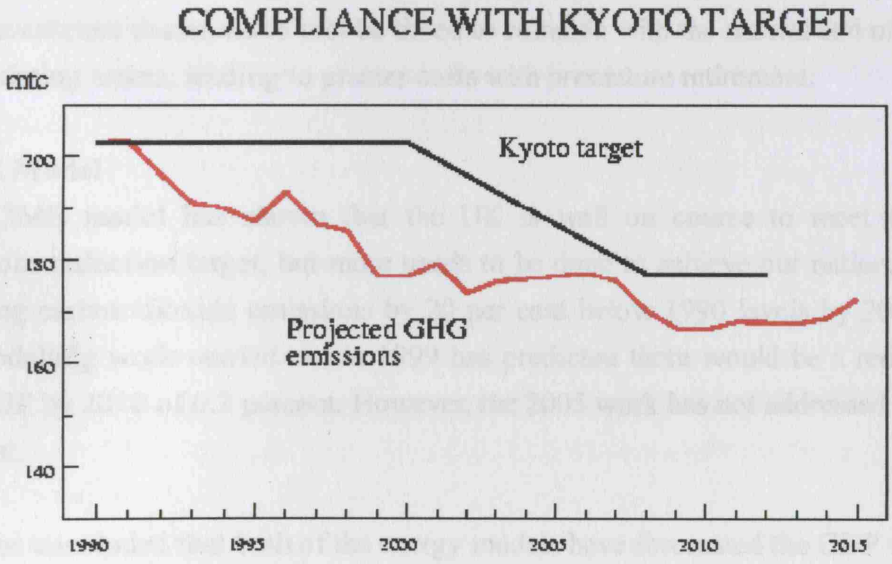

Figure 5.2: Compliance with Kyoto Target[57]

This result has now been acknowledged by the DTI's final energy projections published in November 2004 to inform the UK's National Allocation Plan required for

[56] **Cambridge Econometrics Press Release**, page 2.
[57] **Cambridge Econometrics Press Release,** page 3.

the EU Emissions Trading Scheme.

5.4 Summary and conclusions

Markal Model

For UK to achieve a challenging target of 60 percent savings by 2050, this is done by having innovative technology, increasing renewables use by at least 25% by 2050 and improving energy efficiency In term of economic growth in a low carbon society, the Markal model suggested that there would be a reduction of between 0.01 and 0.02 percentages in the average GDP growth rate over the period between 2000 and 2050. Chemicals, man-made fibers, paper, iron and steel these sectors will be greatly affected by the high oil price. Transport sector will be kept using fossil fuel until 2030 or even later, then hydrogen fuel will take over.

From the Markal study, the solution to keep the impact to the UK economy to minimum is by having a longer transitional period to low carbon economy. The Markal predicts the shorter the period of adjustment, the greater the costs are likely to be due to:

- The substitution possibilities are less;
- Low carbon technology options have less time to develop and fall in Cost;
- Investment decisions cannot be timed to coincide with the natural end of life of existing assets, leading to greater costs with premature retirement.

E3ME Model

The E3ME model has shown that the UK is well on course to meet its Kyoto emissions reduction target, but more needs to be done to achieve our national goal of reducing carbon dioxide emissions by 20 per cent below 1990 levels by 2010. Also, the modelling work carried out in 1999 has predicted there would be a reduction in UK GDP by 2010 of 0.3 percent. However, the 2005 work has not addressed any GDP forecast.

It can be concluded that both of the energy models have forecasted the GDP would be reduced and the process to achieve the carbon dioxide reduction is at a moderate cost. They input to both of the models are heavily depend on new technology, renewables and energy efficiency.

Chapter 6: Discussion

6.1 What would UK suffer the most from climate change?

There are many scientific supports to show that UK climate is changing. UK is feeling an enormous pressure and threat. The main consequence to UK as a country, it is its economy. UK's economy is heavily dependent on burning fossil fuel, the core cause of climate change.

6.2 What has the UK government done to tackle this climate change?

Climate change has been known for last decade but UK government has started to shift to a sustainable economy very recently. UK government has put in lots of effort to make thing right for the Kyoto Protocol and the targets set out in the UK Energy White Paper. As discussed before, the government main strategies are based on developing new technology, so that the use of renewables can be increased considerably. Also, to improve energy efficiency and restrict some business sector energy consumption by climate change levy. But before it solves any problem, it creates more. First of all, confusion of policy documents and work is overlapped between various government departments. Within the UK itself, there are three departments are involved to monitor the energy security issue, they are the Ofgem, FCO and Dti; where Dti and Ofgem have formed JESS, "the Dti/Ofgem Joint Energy Security of Supply Working Group". Since time is crucial, from what the UK government is planning to do, lots of time would be used on communication and meeting. UK should carry out research to find a single energy policy to reduce the carbon emission as a whole. For example, New Zealand has introduced a carbon tax and the people there are expected to pay £1.11 more a week for electricity, petrol and gas. This tax system can persuade people in New Zealand to shift from fossil fuel to renewables. UK government can look at this energy policy and carry our in here. Secondly, there are many brilliant ideas from the various policy documents, but most of them, apart from climate change levy and UK emission trading scheme, have yet to be implemented properly. These policies have influenced the long term business plan of organisations, could lead to slow economic growth or even the worst case, recession. But the government predicts that this threat is very moderate. There is virtually no energy policy on personal energy use and most of the research done by the government has been focused on the production sector. The UK Energy White Paper is heavily depends on new technology, in UK the main factor achieve the desired results. There is no evidence from Markal model to show what new technology is and when the technology can be implemented. It just assumes a magic piece of kit will appear in future to enable lower carbon emission. Hence, there is lots

of uncertainty and the government should not make such an important milestone energy document is based on one single simulation, as this can affect other energy policy in future.

6.3 What is the main factor that would affect the performance of these energy policies?

The most noticeable factor is the sky high crude oil price. Crude oil price has risen to record high of 70 US dollars per barrel (up to 30/08/2005, source from OPEC[58]). This rising oil price actually is not a negative factor. In fact, it would encourage organisations to improve energy efficiency and use of more renewables. Also, the rising oil price would exert a 'good' pressure on new technology development.

6.4 What is the likelihood of achieve the UK Protocol targets and UK government's own target of 20 percent reduction in CO_2 emissions; and the likely costs of these?

The E3ME modelling work has suggested that the UK is well on course to meet its Kyoto emissions reduction target, but more needs to be done to achieve the UK national goal of reducing carbon dioxide emissions by 20 per cent below 1990 levels by 2010. Moreover, the UK GDP will be reduced by 2010 of 0.3 percent due to the CO_2 emissions reduction of 20 percent in the domestic action. This slows down economic growth and contributes to reducing carbon emissions is beneficial for the current generation. For the future generations, there is an uncertain effect, less economic welfare but better environmental quality.

Margaret Beckett, Secretary of State for the Defra also said: "It is clear that we are on track to go beyond our Kyoto target, as emissions of the key greenhouse gases have fallen significantly. However, we will not, on the basis of current policies alone, achieve our ambitious 2010 domestic goal of a 20 per cent cut in carbon dioxide emissions.' Therefore, more or better energy policies are urgently needed to squeeze CO_2 emissions reduction every possible area as there are only 5 years left before 2010.

6.5 What is the future of UK climate change?

There is no definite answer to this question. By judging from the amount of 'effort' the UK government has put into, to plan and implement the energy policies, and the willingness to risk its economic growth in future, a low emission climate change scenario is well deserved. From the already published results of the performance of the various energy policies, UK is also eligible to the low emission climate change

[58] **OPEC**, The Organization of the Petroleum Exporting Countries

scenario. UK may not be able to meet its 20 percents domestic CO_2 cut, but the effort would not be wasted. If the target is not reached by 2010, just extend the time limitation since tackling climate change is a long battle and 'good' effect cannot be seen in a short period of time. UK is doing a lot in terms of making policy and technology research to reduce CO_2 emissions. It is now all down to individual to work together to achieve the researchable but difficult goal, the sustainable future.

6.6 What is the objective of the four energy policy documents?

The UK government's plan of action can be classified into six main objectives as shown in table 6.1. Three of the objectives, to 'improve energy efficiency', 'reduce carbon emission' and 'promote new technologies' are all related to the action of tackling climate change. It can be seen that to 'reduce carbon dioxide emission' is the first priority as it has appeared on the four policy documents. This is the objective that once it has been achieved, the direct or indirect effect will be deteriorated. The UK government strongly believe by improving energy efficiency and using new technology, can lead to a huge reduction of carbon dioxide emissions. Improving energy efficiency is especially important because this objective is cheaper to implement and the technology to achieve this is commonly available. Before these policies published, organisations tend to do as less as possible and they do not use the more energy efficient set up as this is a higher cost option. CCL and emission trading scheme changes all this due to organisations are attracted to the tax reduction which they can benefit from by switching to the more energy efficient option. There is a close link between the objective of 'promoting new technology' and renewables use. Since renewables are a lot more difficult to use in a large scale (apart from nuclear power), a cutting edge technology is needed to be develop to make renewables to become more common. This objective will become more important and always be in the coming energy policy documents.

There are three objectives related to the UK economic growth, they are 'promote energy security', 'promote UK industry' and 'improve rural economy'. UK's economy cannot separate with energy. Energy is like the vessel and vein of the heart of the UK's economy. UK government wants to cut down energy use at the same time to achieve economic growth. There is contradiction between carbon dioxide reduction and economic growth. The feasibility of sustainable economic growth is in doubt; this matter has been addressed the Sustainable Development Commission (SDC), which is the Government's independent advisory body on sustainable development. There is objective of improving rural economy, but the government is lack of action to preserve natural environment at the same time.

There is only one objective related to the social aspect, the 'alleviate fuel poverty'. This reflects the government is lack of research on solving the potential problem come with cutting energy use.

Energy Policy	What is the policy objective?						
	Improve Energy Efficiency	Reduce Carbon Emission	Promote Energy Security	Improve Rural Economy	Promote New Technologies	Promote UK Industry	Alleviate Fuel Poverty
UK Energy White Paper	■	■	■	■	■	■	■
Energy Efficiency Commitment	■	■					■
Climate Change Levy	■	■					
Renewable Obligation		■	■	■	■	■	

Table 6.1: The Main Objective of the Listed Energy Policy.

6.7 How is the production sector affected by this policy?

Table 6.2 shows the sectors that are affected by the four policy documents. The UK Energy White Paper has covered all the energy policy and this is affecting all the production sectors. Energy Efficiency Commitment has a great effect on the domestic sector, but the policy itself is not applied to the domestic sector but the gas and electricity suppliers. These suppliers have to carry out energy efficient improvement work within the domestic sector, where the domestic sector is benefit the most from this policy. This is very similar to the case of Renewables Obligation, electricity suppliers have to start generating from renewable energy under this obligation. They have to research new technology themselves to achieve the increasing demanding obligation. Climate Change levy has the greatest influence as being a single policy. The industry, public and service sectors are affected by this. Any organisations use energy in their business or service is put under this policy. Taxation is a very good way to deal with non-domestic sectors, as this sector's primary goal is to earn money and make profit, to keep flow out of money to minimum where possible. The better they perform under the CCL, the less tax they pay. These organisations are put under pressure to achieve the CCL target to maintain or their profit margin.

Energy Policy	Who does the policy affect?							
	All Sectors	Industry	Energy-intensive Industry	Public Sector	Commerce	Domestic	Transport	Energy Provider
UK Energy White Paper								
Energy Efficiency Commitment								
Climate Change Levy								
Renewables Obligation								Electricity Supplier
Legends:								
Fully Affected								
Partially Affected								

Table 6.2: The Sectors Affected by the Listed Energy Policy.

6.8 Which policy is the most cost effective?

A report entitled *Renewable Energy*[59], published recently by the National Audit Office analysed the cost of various policies to reduce carbon emissions as shown in Table 6.3.

Policy	Cost (£/tonne CO2)
Energy Efficiency Commitment	-16
Climate Change Levy	5 to 11
UK Emissions Trading Scheme	18
Renewables Obligation	70 to 140

Table 6.3: Cost of Different Policies to Reduce Carbon Dioxide Emission

One can see that the EEC emerges as the most cost efficient mechanism, followed by UK emissions trading scheme and CCL. Renewables Obligation loses out in this analysis because of the investment made into the new technology and rural economy uncertainty. Renewables Obligation is worth the investment for long term because it provides UK energy security, which the other three policies do not.

[59] Association of the Conservation of Energy, **Review of the Climate Change Program,** http://www.ukace.org/pubs/consult/Defra%20Review%20of%20UK%20Climate%20Change%20Programme%20(ACE%20response).pdf

Chapter 7 Conclusions

7.1 Brief Summary of the Four Energy Policies

UK government has a great ambition to achieve a low-carbon economy.

The UK Energy White Paper has set a very high goal both environmental and economic. The white paper policy is very mild but goals set require aggressive policy. It may look good on paper but it shows contradiction. Especially, the reduction on carbon dioxide can lead to a higher economic growth. UK government is heavily dependent on improving energy efficiency and developing new technology to meet this target. If one of these two factors goes wrong, target won't be met. Has UK government got any back up plan? Several key elements (plans) should run in parallel, if one has failed other can be kept going to meet the target. The problem is a lot of resources (both human and money) are required.

Energy Efficiency Commitment has done a great job in improving the fuel poverty in the domestic sector. The gas and electricity suppliers have followed the plan and the strategy is working very well.

Climate change levy and UK emission trading scheme can kill of some less competitive company and business during early stage of implementation, which can lead to other political and economic problem.

The progress of the Renewables Obligation needs be carefully monitored, alongside other closely related factors including emissions trading, wholesale electricity prices and primary fuel prices, as its effectiveness and public acceptability are likely to be judged in relation to these wider trends.

Increasing numbers of documents and reports are published in conjunction to the UK energy white paper. The documents reviewed here is just a small friction. The level of work to achieve the white paper goals are getting more complex, as one has to refer to different documents and the policy is kept updating. (UK energy policy change, other Industrial Guide book has to change with this). Renewable is the next big movement in energy, but more work has to be done in the RO and the government has been kept consulting and made progressive changes.

7.2 Key Findings

7.2.1 Pros and Cons of the Four Energy Policies

The pro and con of the four energy policy document is summarised as below.

UK Energy White Paper

Pro

- Master plan for other energy policy and full of information
- Include energy saving strategy for all sectors
- Set trend for renewables use
- Mild policy as a whole to allow freedom and time to adopt
- Policy to ensure energy security in future e.g. Energy generates locally even UK will become net energy importer in future
- Set out simple and effective strategy to solve fuel poverty in domestic sector

Con

- Many plans needed to put into action
- Strategy requires work carried out across different government functional groups, may cause communication difficult and reduces the effect of the strategy.
- High goals are set (especially on renewables) and some are optimistic
- To achieve this high goal, it requires a more aggressive plan.
- Not enough strategy to control or ease the effect of the rising oil price
- There is no single energy policy
- Too many proposed actions, need to strike a balance and put efforts on those are effective.

Energy Efficiency Commitment

Pro

- Encourage gas and electricity suppliers to install efficient installation, priority households in particular.
- Alleviate Fuel Poverty
- Improve Energy Efficiency
- Very cost-effective

Con

- May create extra burden to gas and electricity supplier

Climate Change Levy and UK Emissions Trading Scheme

Pro

- Encourage the reduction of carbon emission through taxation
- Organisations meeting the target can benefit from tax reduction, a good driving force for them.
- Improve Energy Efficiency
- Establish UK as a trading centre

Con

- Money orientated scheme, bad initiative in environmental context.

Renewables Obligation

Pro

- Promoting the cheapest and most established renewable technologies.
- Help to improve UK energy security
- Promote the development of new technology

Con

- Loss of the countryside through the construction of related infrastructure such as power stations.
- Expensive to implement

7.2.2 Improvements to the Four Energy Policies

Firstly, the data collected by the government is needed to be improved. Although there is many data, the data is not organised very well. Poor data collection can affect the policymakers in many ways, especially in macro-scale modelling. Secondly, there should be research carrying on personal energy use. Thirdly, the UK government should pay more attention on opportunities for other production sector created by the energy policies. The implementation of these energy policies can reallocate the resources in the UK's economy. Fourthly, the UK Energy White Paper should address the problem and solution related to the UK's sustainable economic growth. Finally, the policy documents should have told the public that long-term policy can result to an increase in consumption in short run i.e. more energy spent on research there is a pay-back-period.

7.3 Evaluations of this Thesis

7.3.1 Limitations of this Research

The main limitation is on the macro model study, there is lack of information on books, journals and internet. When the relevant document and modelling results were found on this macro model, restrictive access to this information has taken away the chance to review this information.

The UK government has produced many energy policy documents. The 'Con' addressed of the four documents might have been covered in those documents that have not been reviewed in this thesis. Therefore, to be able to understand the full picture of UK energy policy, it is better to investigate all the energy policy related documents and incorporated them together, which is not possible in this MSc thesis.

7.3.2 Were the Aim and Objective Achieved?

Let's recap the aim and objective of this thesis.

The research questions are:

- What are the pros and cons of the various UK energy policy documents?
- What are the impacts of currently proposed environmental policies in UK on economic growth in the 21st century?

In order to achieve these aims and answer these questions, the following objectives have been set out:

- Investigate the UK climate change.
- Present UK climate change data.
- Identify and investigate the main cause of UK climate change.
- Review selective UK energy policy documents
- Investigate and present macro-scale energy model.

To answer the first questions, the following four documents have been looked at:

- **UK Energy White Paper**
- **Climate Change Levy and UK Emissions Trading Scheme**
- **Energy Efficiency Commitment**
- **Renewable Obligation**

The second question is answered by examining macro-scale energy model of Markal and E3ME.

This thesis has investigated the UK climate change, and identified the main cause of UK climate change. Four UK energy policy documents were reviewed and two macro-scale energy models were also studied. . The analysis was made about these policies and the pros and cons were concluded. The impact of the energy policies on economic growth in the 21st century is discussed. Therefore, the aim ad objective of the thesis has been achieved.

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Appendix 1: Sector Associations with agreements or in negotiation with Defra

Aluminium Federation	Non-Ferrous Alliance
Brewers & Licensed Retailers Association	Reprotech (waste pellet manufacturer - sole company in sector)
British Apparel and Textile Confederation	Shipbuilders and Shiprepairers Association
British Cement Association	Slag Grinders Association
British Ceramic Confederation	Spirits Energy Efficiency Company
British Egg Industry Council	Society of British Aerospace Companies Ltd
British Glass Manufacturers Confederation	Society of Motor Manufacturers and Traders Ltd
British Leather Confederation	Surface Engineering Association
British Lime Association	Target 2010
British Marine Industries Federation	The Paper Federation
British Meat Federation	UK Agricultural Supply Trade Association
British Poultry Meat Federation	UK Renderers Association
British Printing Industry Federation	UK Steel Association
British Rubber Manufacturers Association Ltd	Vehicle Body Repairers Association
Chemical Industries Association	Wallcovering Manufacturers Association
Confederation of British Metal Forming	Wood Panel Industries Federation
Dairy Industry Federation	
Eurisol (mineral wool manufacturers)	
Food and Drink Federation	
Gypsum Products Development Association	
Maltsters Association of Great Britain	
Metal Packaging Manufacturers Association	
National Association of Master Bakers	
National Farmers' Union	
National Microelectronics Institute	

Appendix 2: Eligible Renewable Sources

Landfill gas	Yes
Sewage gas	Yes
Hydro exceeding 20 megawatts declared net capacity (dnc)	Only stations commissioned after 1 April 2002
Hydro 20 megawatts or less dnc	Yes
Onshore wind	Yes
Offshore wind	Yes
Co-firing of biomass	• Any biomass can be co-fired until 31 March 2009 with no minimum percentage of energy crops • 25 per cent of co-fired biomass must be energy crops from 1 April 2009 until 31 March 2010 • 50 per cent of co-fired biomass must be energy crops from 1 April 2010 until 31 March 2011 • 75 per cent of co-fired biomass must be energy crops from 1 April 2011 until 31 March 2016 • Co-firing ceases to be eligible for Renewable Obligation Certificates (ROCs) after 31 March 2016.
Other biomass	Yes
Geothermal power	Yes
Tidal and tidal stream power	Yes
Wave power	Yes
Photovoltaics	Yes
Energy crops	Yes